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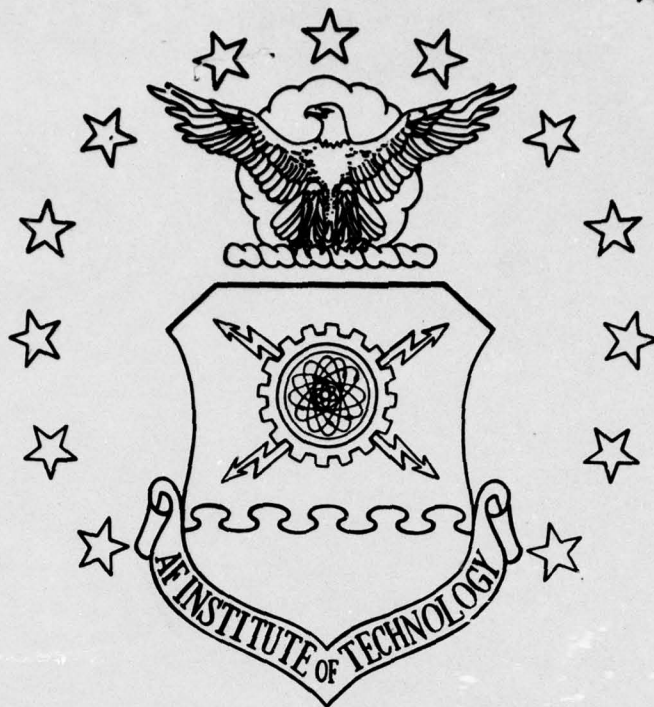
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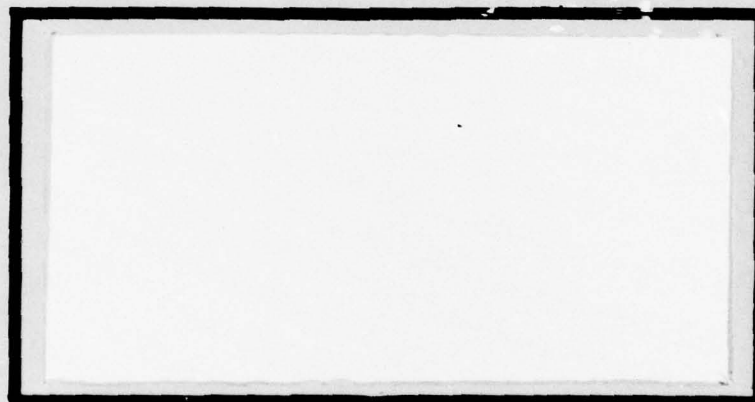
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INTEGRATING OPTIMUM REPAIR-LEVEL ANALYSIS
AND INVENTORY DECISIONS INTO THE
LOGISTICS SUPPORT COST STRUCTURE

THESIS

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Paul E. Taibl
Capt USAF



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(See 1473)

INTEGRATING OPTIMUM REPAIR-LEVEL ANALYSIS
AND INVENTORY DECISIONS INTO THE
LOGISTICS SUPPORT COST STRUCTURE

THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science

by

Paul E. Taibl, B.S.

Capt. USAF

Graduate Operations Research

December 1976



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Preface

This study grew out of my interest in the logistics support aspects of Air Force weapon systems. During previous assignments, I had seen the mammoth investment made by the Air Force in maintenance and supply facilities, spare parts and support equipment. My tour of duty at the Air Force Institute of Technology and its close proximity to the headquarters of the Air Force Logistics Command has enabled me to investigate the support planning and design considerations that precede the Air Force decision to invest in supporting logistics systems.

The study is, I think, a relatively complete analysis of three of the analytical models which are used in logistics acquisition. The intent is not, however, to dissect the models but to make them better understood and to propose a method of integrating both the data inputs and best features of the models so that support planners may possibly make better decisions with them. Many readers will judge that I have directed the study at potential model users new to the logistics acquisition field. This was not done deliberately, but is a consequence of my own membership in that group. In this, I take full responsibility for any resulting inaccuracies and omissions of detail.

Finally, I wish to acknowledge the indispensable assistance provided by my wife in translating the manuscript into this final report.

Paul E. Taibl

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List of Abbreviations

1. CREATE - Computational Resources for Engineering, Simulation, Training and Education. The computer system located at HQ AFLC.
2. DPML - Deputy Program Manager for Logistics. The logistics deputy in the System Program Office.
3. EBO - Standard established for expected backorders. (backorder - an unfilled demand at base level.)
4. EOQ - Economic Order Quantity.
5. FLU - First Line Unit. First level of assembly below the system level and usually the highest level of assembly that is removed and replaced as a single unit.
6. ILS - Integrated Logistics Support.
7. LCC - Life Cycle Cost.
8. LRU - Line Replaceable Unit. An assembly which can be removed as a unit from the system at an operating location. For purposes of this study, it is identical to FLU.
9. LSC - Logistics Support Cost model.
10. MOD-METRIC - Modified Multi-Echelon Technique for Recoverable Item Control model.
11. MTBD - Mean Time Between Demands. The average number of operating hours accumulated on a unit when it is removed from a next higher assembly and a request is made for a supply replacement.
12. MTBF - Mean Time Between Failures expressed in operating hours in the operational environment.
13. NRTS - Not Repairable This Station. Indicates that a removed assembly must be returned to depot for repair.
14. OR - Operationally Ready.
15. ORLA - Optimum Repair-Level Analysis model.
16. SCALE - Systematic Cost- and Logistics-Effectiveness procedure.

- 17. SE - Support Equipment used to maintain a system or assembly.
- 18. SRU - Shop Replaceable Unit. A module for an LRU which can be removed at an intermediate repair facility.
- 19. Subsystem - A category of equipment subserviant to the overall weapon system, such as: avionics, airframe, powerplant, fire control, etc.

Abstract

The concept of Integrated Logistics Support (ILS) has emphasized the use of models to investigate the quantitative aspects of logistics acquisition management. According to a Rand Corporation report, sufficient models exist to satisfy the needs of ILS but additional effort is required to streamline the use of the models and make them more accessible to potential users. The Systematic Cost- and Logistics-Effectiveness (SCALE) procedure is a recent attempt by Battelle Columbus Laboratories to conceptualize a framework in which specific mathematical models would interact in a logistics support context. LSC, ORLA and MOD-METRIC are three of the Air Force models proposed for SCALE integration. They contain considerable overlap in input requirements and lack a working vehicle for resolving model-to-model inconsistencies. This study shows that a FORTRAN-based consolidation routine reduces input requirements by one third and allows the user to build a single data array that can be accessed by any of the models. The input routine also facilitates the use of certain key outputs (described) which make it advantageous to integrate the models in a sequential fashion. The report includes an analysis of the models, the routine and a user's guide.

Chapter I

Introduction

In recent years, the Air Force has intensified its commitment to the Department of Defense concept of Integrated Logistics Support (ILS) --- a program designed to assure "the effective economical support of a system or equipment throughout its life cycle (Ref 1:2)." Air Force emphasis has been on using analytic and simulation models to conduct design and support analyses. According to a 1971 Rand Corporation report, the mathematical techniques and models already available are sufficient to accomplish the aims of the ILS concept (Ref 3:47). There is, in the opinion of the Rand study, an overriding need to combine models into compatible families and educate designers and logistics planners in their use.

This study is an attempt to integrate three distinct models which are currently being used within the Air Force Logistics Command. They are:

1. LSC. A model which estimates the expected support costs that may be incurred by adopting a particular design.
2. ORLA. A level of repair model which calculates costs associated with each of three maintenance policies --- discard at failure, repair at intermediate level, or repair at depot level.
3. MOD-METRIC. An optimal spares provisioning model which computes base and depot stock levels for items which enter the repair cycle.

These models focus on the central issue of logistics acquisition management --- design and procurement of systems and hardware which

satisfy operational requirements for the lowest total cost of ownership to the government.

Chapter II traces the development of ILS within the Department of Defense and the Air Force. Chapter III describes the specific types and capabilities of models used in logistics acquisition. As such, Chapters II and III provide general background to the study which may be of interest to the reader. They are not, however, prerequisite to the central theme of this report and can be omitted without loss of continuity to the attempt at integrating the LSC, ORLA and MOD-METRIC models.

Beginning in Chapter IV, the study focuses on developing an integrated framework for the three models. Because of the wide variance in context in which they are used, it is necessary for the models to retain their individuality. But there is obviously a common purpose in their use. This study capitalizes on that common purpose --- minimizing support cost --- by employing the LSC model as the basic analytic tool to support the logistics acquisition process. Within this framework, the input requirements of the ORLA and MOD-METRIC models are made compatible with LSC input parameters. To structure the objective, the study describes the respective roles of the models within the acquisition cycle and explores their common assumptions and input variable requirements. To implement the process, two alternative procedures are presented:

1. A routine which transforms input variables into a data array which can be accessed by any of the three models.
2. An iterative scheme which allows integration of the ORLA and MOD-METRIC models with subsets of the LSC model.

Throughout, an attempt has been made to reinforce the management potential of analytical modelling. At the same time it is hoped that the models themselves will become better understood, more easily accessible and responsive to the logistics acquisition manager.

Chapter II

Development of Integrated Logistics Support

In 1964 the Department of Defense formalized the concept of Integrated Logistics Support. This policy required that all of the services consider, estimate and evaluate the life cycle costs associated with the various design alternatives encountered during the weapon acquisition process. Two related forces were emerging within defense and defense related industries which began to alter the prevailing perceptions of weapon system acquisition. First, the phenomenon of "cost growth" began to appear not as an occasional result of the risks associated with advanced technology but as a steady companion of other trends in the economy --- higher personnel costs, increasing weapon complexity and low equipment reliability (Ref 2:1). It was no longer an aberration to have a weapon system come into the operational inventory at twice the original procurement cost estimates. The second transition was directly related to the first. It came in the recognition that total costs of ownership, especially operating, training and support costs, were increasing at an equally dramatic rate. The term "life cycle costs" became more and more commonplace in the lexicon of the military planner.

By 1965 some estimates attributed more than half of a weapon system's life cycle cost to operating, training and support --- the so-called "logistics" costs of ownership (Ref 4:3). It became apparent that to acquire improved weapon systems for national defense,

and to prevent placing an ever expanding burden on the American taxpayer for support of existing weapon systems, an effective policy of logistics support planning would have to become an integral part of all aspects of system acquisition and operation. DOD Directive 4100.35, which described the concept of ILS, became the impetus of the logistics acquisition program.

Following the publication of the ILS directive, each of the armed services began to reorient major portions of their weapons acquisition procedures. Renewed emphasis was placed on developing models based on mathematical relationships which could, in effect, collapse and summarize the complex problems facing acquisition managers into compact cost-estimating relationships and simulations of the operating environment. A report prepared for Air Force Project Rand, which will be discussed later in greater detail, concluded that by 1970 enough models existed to fulfill the needs of ILS (Ref 3:vii).

ILS Concept

There were other factors which spurred the emergence of ILS. The mounting pressure to redirect national priorities and continued congressional and public scrutiny of the burgeoning costs of military hardware signalled the Department of Defense to anticipate relatively constant defense budgets (Ref 2:1). This implied that in real terms less funds would be available to develop new systems and that the services would have to perform their missions with fewer, more costly, systems and fewer personnel. The challenge was clear: develop new systems which could be bought at lower unit cost, that would demonstrate higher reliability and maintainability, and which could achieve acceptable levels of performance. When combined with higher personnel

costs and increasing weapon complexity, the urgent need to implement ILS received added emphasis. The 1970 version of DOD Directive 4100.35 defined ILS as twofold:

...a composite of all the support considerations necessary to assure the effective and economical support of a system for its life cycle (Ref 1:2).

and,

...an integral part of all other aspects of system acquisition and operation. Design... shall take into account the aspects of logistic support.... Tradeoffs appropriate to the stage of development shall be made that will maximize the effectiveness and efficiency of the support system.... The operational environment, and the logistic support requirements which are the result, will be addressed during the tradeoff stage of the system design process. Change to either the system or to logistic support needs will be fully evaluated for the impact on the total system (Ref 1:2-4).

The technical policies promoted by the directive instruct the services to employ "techniques for analysis and definition of system qualitative and quantitative support values and associated costs (annual and life cycle)... (Ref 1:4)." Clearly the purpose and preferred method for initiating ILS had been set down for the armed services.

ILS Implementation

Underlying the need for ILS is the observation that, historically, support costs have not been of major importance to system designers because funding arrangements often separate research, procurement and support monies into different unmixable "pots" and because these funds are appropriated at different --- sometimes widely spaced --- points in the acquisition cycle. An even more fundamental problem was that credible cost estimates were not available early in the

in the process (Ref 3:2-3). The current DOD ILS effort focuses on these related problems by seeking to insure that logistics plans develop the support posture in response to the design decision and, conversely, consider the alternatives to the design decision and, if necessary, alter the design to exploit significant economies in the support area. To accomplish these aims requires that systems receive thorough, credible analysis; come under review early in the life cycle; and receive support from all management and policy levels that can affect decisions (Ref 3:3).

If assessed correctly, the causes and treatment of systems acquisition pitfalls as propounded by DOD have adequately circumscribed the reasons for implementing ILS. It may be instructive to consider how an independent group viewed the process of attaining economies in systems acquisition.

The Fitzhugh Report

The Fitzhugh report was the outgrowth of a blue ribbon defense panel convened by the President to study a wide range of topics under the heading of "Defense for Peace". In the report, which was published in 1970, the services were enjoined to do better in estimating both the investment and support costs of new systems. The panel emphasized the importance of considering future maintenance costs as part of a system's acquisition cost. It recommended that support policies be adopted in which "repair in lieu of replacement should be an allowable charge against the parent procurement appropriation funding the basic equipment (Ref 5:II-31)." This is in line with the ILS proposal to include in the design considerations all costs which might accrue during the system's life cycle.

The report echoed the requirement of the DOD program in the area of conducting thorough analyses. Although the Fitzhugh report placed greater reliance on actual hardware prototyping and testing, its main thrust was to encourage the collection of factual experimental data which would serve to reduce technological uncertainty and thereby make system analyses more credible. Such data could be provided early in a system's life cycle, according to the report, if "development of selected subsystems and components is carried out independently of major systems (Ref 5:II-5)."

In another area, the panel urged that tradeoffs be conducted between new systems and that support considerations be appended to programs concerned with product improvement and modification of current systems --- areas that were just coming under scrutiny of DOD (Ref 5:II-5). Overall, it appears that the report of the Fitzhugh panel was in consonance with the objectives of DOD's ILS program, particularly in urging thorough analyses early in the acquisition process.

The Rand Report

A 1971 Rand report on Using Logistics Models in System Design and Early Support Planning provided an in depth description of the modelling techniques available through 1970 which could be used to investigate the logistics impacts of system design and operational decisions during system acquisition. Prepared for U.S. Air Force Project Rand, the study was addressed to system designers, program managers, logistics planners and staff planners responsible for implementing ILS concepts. It took a wide view of the purpose and process of logistics modelling in order to clarify how some of the tasks required by the ILS concept might be performed.

The Rand report developed the treatments prescribed in DOD Directive 4100.35 by putting logistics models into the contexts of data requirements, application points in the development cycle and policymaking expectations of acquisition managers. It emphasized that data must represent the engineers' best estimate of the system and its descriptive parameters; models must represent the support process, be readily useable and economical to operate; personnel must be trained in the use of analysis and must understand the role models play in support decisions (Ref 3:3). Seen as a common thread running through all reviews of ILS objectives is the stricture in the Rand report that analysis should begin early in the system's life cycle, adding that "at this point it is less costly to rectify mistakes; it is easier to adjust design objectives; and it makes studies and tradeoffs more meaningful since ... a broader set of specifications can be influenced ... (Ref 3:3)."

The most significant contributions of the Rand study were its succinct conclusions and recommendations on the state of logistics modelling within the ILS concept:

... model technology is well in hand to do the support cost estimating required for implementing integrated logistics support in all phases of the system acquisition process. Such estimating is most difficult in the early conceptual phase, but techniques are available to handle the uncertainty inherent in such early data.

... a sufficient stock of basic models and modeling techniques is available ...

Primary development effort should probably be devoted to adapting existing models to particular applications, and to interfacing sets of models into compatible families

... individuals who could best use models must be instructed in analyzing the support cost consequences of varying operational requirements, different hardware designs, and alternative support postures. ILS will never realize its full utility ... without such training for system and support planners (Ref 3:47).

The Air Force ILS Program

The Integrated Logistics Support program in the U.S. Air Force has been responsive to the DOD concept and influenced to a great degree by the work that has been done in studies like the Rand report. In recent times, the Air Force has sponsored some of the most complex and costly weapon systems proposed for national defense. This makes it imperative that any savings that might accrue from pursuing a fervent policy of ILS be exploited and taken for advantage. Official policy concerning ILS within the Air Force is described in AFR 800-8 which states:

Management information and program control techniques shall provide for effective management control of ILS elements to include the maintenance of traceable estimates and factors for cost acquisition and ownership of the system or equipment (Ref 6:3).

The regulation establishes the following principles of ILS:

ILS must be considered during the early phases of conceptual development, validation, and full-scale development ... when trade-offs can influence hardware design.

ILS as an interdisciplinary concept is dedicated to achieving the optimum performance-schedule-cost-support relationship.... It requires special emphasis on,

- (1) developing or improving techniques for conducting trade-offs among support alternatives
- (2) performing system and cost-effectiveness analysis
- (3) using models to conduct design and support analyses ...
- (4) accomplishing evaluation during appropriate source-selection processes.

Overall operational effectiveness, the prime consideration when acquiring a new system or equipment, can be achieved by system and cost-effectiveness analysis. Emphasis must be placed on achieving proper balance between performance and logistics (Ref 6:2).

Application of ILS within the Air Force is chiefly vested in the Air Force Logistics Command (AFLC). Although the principles are applied throughout the command, responsibility is levied primarily on the Deputy Program Managers for Logistics (DPML) who are assigned to the program office which oversees each new weapon system (Ref 6:3). In July 1976 the Air Force Acquisition Logistics Division (AFALD) was established at Wright-Patterson AFB, Ohio, with a charter to coordinate and support the detailed analyses required by the DPML. Although the logistics acquisition structure is much more detailed, it is probably sufficient to note its basic form and go on, instead, to see how one current challenge will affect Air Force ILS planning.

The potential acquisition of the B-1 bomber has far ranging implications on the Air Force and, in particular, the application of ILS. The procurement cost of the B-1 is expected to exceed \$2 billion each year starting in fiscal year 1978 (Ref 7:29). Comparing this with the Air Force appropriation for aircraft procurement which has remained relatively constant at \$3 billion annually for the past several years, it is evident that planners must apply ILS concepts in all procurement areas to maintain the overall aircraft modernization program. Some of the key elements which will enable the Air Force to manage this logistics acquisition programming challenge have yet to be worked out. There is still the need to streamline the ILS modelling process by interfacing families of

Chapter III

Logistics Support Modelling Concepts

The models used to support the Logistics acquisition process take many forms and generally include one or more of the following elements: cost estimating relationships, cost accumulating methods, mathematical equivalencies or simulation techniques. The models themselves may take the form of the flowcharts, graphs, "think pieces", or elaborate computer routines. All models attempt to capture a particular view of the world.

When an analyst builds a model, he is essentially posing a solution to a problem in a manner which is both explicit and quantitative.

1. He decides which factors are relevant to the questions his study is attempting to answer.

2. From these he picks the quantifiable factors --- those that can be described numerically.

3. This list is cut down to size by aggregation.

4. The relations between the elements are spelled out quantitatively (Ref 8:68).

The resultant model is then verified and, where possible, tested against the real world.

In light of the preceding, model building is a very straightforward, deliberate procedure. The crux of the modelling process, however, is not developing the model but defining the problem to be solved. This requires the analyst to adopt some particular view of the world and some singular approach to formulating it. The result

is that no single model can serve every purpose; in fact, the Defense Logistics Studies Information Exchange has a catalog of over 500 models which have been devised to deal with varying aspects of logistics support.

Types of Models

The logistics acquisition manager is confronted with three related decision situations: concept evaluation, detailed design and support planning (Ref 3:6). Incorporated in each of these tasks is the requirement to make comparisons within four more substantive areas: spares provisioning, support equipment requirements, personnel requirements and maintenance posture. Logistics models are well suited to make the comparisons because of the quantitative nature of these elements. The models used generally fall into two categories, simulation and analytic.

Simulation models are the more exotic of the two. They can yield sizable solution sets and handle large data inputs. Simulations are represented as procedures, generally executed on a computer, in which elements of the situation are represented by arithmetic and logical processes that predict the dynamic properties of the situation (Ref 9:8). Implicit in simulation is the concept of condensing time thru use of a high-speed computer with numerical "snap-shots" of the system at critical moments being recorded for review by the analyst. These models have their primary usefulness in establishing a system's characteristics under a particular support posture.

Analytic models are characterized by unique sets of answers or point estimates. Time is treated as an interval estimate rather

than a dynamic variable. While the number of parameters which bound the model usually are not restrictive; the numerical methodology which underlies the computation is often minimal, enhancing efficient, simple calculation (Ref 3:10). When computerized, most analytic models search for solution sets by manipulating a sequence of equations in an iterative fashion. In contrast to simulations, individual analytic models tend to focus on one aspect of a problem (such as spares or level of repair) at a time. The three models discussed in Chapter V are examples of analytic models.

Input Requirements

Regardless of the type of model chosen to make a comparison or trade-off analysis, certain data inputs are necessary to initiate the modelling process. Some of the most important, taken from the 1971 Rand report, are summarized in Table I. As the table suggests, the models used in logistics planning rely heavily on historical data translated into standard values for the tasks to be performed. Costs for labor and repair are the foremost examples. Model inputs which refer to system peculiar items are usually engineering estimates provided by the contractor or interpreted from operational experience with similar systems. Other variables, such as basing strategy or spares reorder points, will reflect the policy considerations proposed for the system.

Not all of the elements listed in Table I are necessary for every logistics model. Depending on the purpose of the model, many of the parameters may be calculated as part of the output. Chapters VI and VII address the commonality of input requirements in one set of logistics models and the possibility of satisfying data requirements by translating outputs of one model into inputs for another.

Table I
LOGISTICS MODEL VARIABLES

ITEM	REPAIR POINTS
Unit cost	Manhours to repair
Reliability	Skill shredouts
Weight	Parts cost/repair
Volume	Labor rate
Procurement lead time	Repair cycle length
Replacement cost	Order and shipping time
R & D cost	NRTS rate
	Condemnation rate
SYSTEM	Base-depot distance
Utilization rate	Packing cost
Basing strategy	Shipping cost
Force size	Support equipment cost
Design life	(life cycle)
OR rate	Support equipment weight,
On-equipment maintenance cost	volume and quantity
Training cost	New facilities cost
Interest rate	Tech data cost
SUPPLY POINTS	MAINTENANCE POSTURE
Spares level	Discard-at-failure
Supply effectiveness	Intermediate repair
Supply administration cost	Depot repair
Reorder policy	

(adapted from Ref 3:8)

Model Categories

The application of models which directly support the logistics phase of acquisition management can be divided into five categories: spares, support equipment, personnel, level of repair and life cycle cost (Ref 3:16). When examining the available models, these categories can be condensed even further. The computation of support equipment and personnel requirements is highly dependent on level of repair decision and constitutes a large portion of life cycle cost. Therefore, most level of repair and life cycle cost models include these calculations as part of their analyses. The following segments

attempt to define more precisely the nature of the three remaining categories: spares, level of repair and life cycle cost.

Spares Provisioning

Spares models are the most analytically sophisticated of the logistics support models. The most recent designs use variations of classical optimization techniques --- such as Generalized LaGrange Multipliers --- to arrive at a spares provisioning posture. The process involves optimizing a specific quantity (like fill rate, backorders, Not Operationally Ready - Supply (NORS) or Operationally Ready) subject to constraints on time, investment cost, number of operating locations and the like. In their computations, spares models require inputs concerning utilization, item failure rate and repair time. In choosing a spares model it is important to consider how it treats the indenture or hierarchical nature of the recoverable asset and the manner in which failure rates are determined. These areas will be discussed in connection with the MOD-METRIC Model in Chapter V.

Level of Repair

Level of repair refers specifically to the maintenance posture adopted or proposed for a particular system. In the Air Force, maintenance posture has historically been two-echelon --- that is, repair at base or repair at depot. To make this determination, level of repair models generally employ accumulating methods which result in a comparative measure of life cycle costs for the system if repaired at separate levels. At the same time the model will accumulate initial inventory costs and subsequent replacement costs for an asset

if discarded at failure. While not a level of repair decision per se, discard at failure is a viable alternative to a two-echelon system; especially when components are high-volume, fast turnover items.

Level of repair decisions are principally driven by estimates of cost for initial spares, cost for new repair facilities (including support equipment), repair/resupply costs (men, materiel, transportation) and ancillary costs like training, technical data, etc. (Ref 3:22). Most models calculate these estimates from standard value and engineering data inputs. After the cost comparisons indicate which maintenance posture is most economical, the man-hour and machine utilization rates can be translated into personnel and support equipment requirements.

One problem that arises in using level of repair models is that most attempt to make an optimal spares provisioning calculation to facilitate comparison of systems at levels of equal effectiveness (Ref 3:23). In actuality, supply policies normally stipulate a specific supply effectiveness which is less than optimal because of control and standardization considerations. The result is that repair-level analyses will accurately portray the rankings of life cycle costs for different systems; however, these costs cannot be viewed as accurate estimates of true operational costs. A detailed treatment of reconciling optimum spares policy with the Air Force supply system procedures was developed by Stephen Enke in 1958 (Ref 10:266-281). As he points out, the problems remaining are formidable and, as of this writing, the institutional difficulties have yet to be completely resolved.

Life Cycle Cost

Life cycle cost models can be described as umbrella models: they

try to encompass all costs associated with adopting a particular design. Because of this, they do not normally contain overly rigorous treatments of the individual components which constitute the model such as spares provisioning and level of repair. Yet life cycle cost models can be the most important techniques used by an acquisition manager because they generate the aggregate measures of performance and support necessary to conduct tradeoff analysis and final source selection.

In practical use, models which deal with cost accumulation over the design life of a system are referred to as life cycle cost models. It would be more accurate to characterize these models as "logistic support cost" models because, as was noted in Chapter II, well over half of the total life cycle cost is chargeable to logistics support. Since initial procurement costs are, in effect, sunk; it would be only mildly facetious to conclude that support costs are the only manageable costs which accrue during a system's life cycle. This is, of course, an oversimplification. Life cycle cost models can be applied early in the acquisition cycle to do the following tasks:

1. Examine the impacts of operational requirements on design and support alternatives.
2. Highlight costly support requirements resulting from design decisions and indicate design change alternatives.
3. Compare alternative support postures.
4. Develop budget estimates during the advocacy process.
5. Act as evaluation tools in the source selection process (Ref 3:30).

Models which attempt to quantify life cycle costs best achieve the aims of the ILS concept because they force consideration of future support requirements while providing the framework for support planning once the final design is selected.

One final aspect of life cycle costing should be noted. The models which have been designed to make cost estimates are often criticized because of the wide variances that occur between predicted costs and actual life cycle costs. There is much explanation yet little argument over this fact. It does not however, diminish the usefulness of LCC models. The comparisons performed by these models among systems, design considerations and support postures will indicate early in the acquisition process the most economical choice, regardless of the actual magnitude of the final pricetag.

Summary

This chapter has attempted to define, albeit rather generally, the process of modelling and the types of logistics oriented models available to the logistics acquisition manager. Ideally, models are not viewed as remote, uncompromising black boxes or, conversely, as possessing an overabundance of mystic powers. According to one practitioner in the art of modelling, model building is based on human judgement, intuition and guesswork. The results that come, often with high precision, from a model must be viewed in this light (Ref 8:77). The human input is an important factor to consider when working with logistics models. The impulse to make decisions simply because results came from "the model" can be overwhelming if one listens too long to what is touted about models. Fortunately, as Herman Kahn notes,

Today, systems analysts are getting to be both more modest about their claims and better at their work. If the trend continues, we may well come out with a match between claims and product (Ref 11:37).

Chapter IV

Integration of Support Cost, Level of Repair and Spares Provisioning Models

This chapter is concerned with the specific problem of integrating various types of logistics support models into a useable framework. Although a large number of such models are used to support the ILS concept, the study focuses on three Air Force developed models. This chapter deals with the scope and methodology which will be used to investigate these three models in the following chapters.

The SCALE Proposal

Several attempts have been made to conceptualize a framework within which sets of models would interact in a logistics support context. In addition to the Rand report already cited, Boeing Aerospace Corporation and the Logistics Management Institute have each investigated the adaptability of specific logistics support cost techniques to an overall ILS framework (Ref 2:7). The most recent effort in this area is the Systematic Cost- and Logistics-Effectiveness (SCALE) procedure developed during 1975 by Battelle Columbus Laboratories of Columbus, Ohio, for the Air Force Logistics Command. One of the ancillary findings of the SCALE report was that similar attempts to portray the interrelationships among logistics models, although seemingly successful on paper, were never made operational. This, the report said, was largely due to the absence of guidelines

for use of the models and lack of a "working vehicle ... for conveniently resolving model inconsistencies and making them more accessible and responsive (Ref 2:7)."

The SCALE proposal attempts to resolve the shortcomings of previous efforts. The concept has as primary goals and features:

1. Use of existing models.
2. Consistent input/output.
3. Interaction of models.
4. Quick response by a broad spectrum of users.
5. Hierarchical framework for relevant application at each stage of weapon system development and subsequent operation.
6. Balanced consideration of elements of logistics support and operational effectiveness.
7. Central model control and responsive adaptation to new systems (Ref 2:3-4).

As an adjunct to defining the concept of the SCALE procedure, the report analyzes the peculiar characteristics of existing logistics models and selects models for potential integration into a SCALE framework.

The Battelle investigation eliminated early-on the quest for a large model combining all the "best" features of existing models on the basis that such a model would be so comprehensive that only its designers would be knowledgeable enough to use it and that such an effort thwarts the many users who need to investigate only elemental portions of a logistics support problem (Ref 2:4). The SCALE developers also determined to select only well-established logistics models so that the appearance of the models in an integrated framework would require minimal relearning. This narrowed the field of model candidates to 26 and eventually seven were chosen to establish a

SCALE capability:

1. LSC. An Air Force model which accumulates logistics support cost.
2. MOD-METRIC. A comprehensive Air Force inventory model.
3. ORLA. An Air Force procedure for level of repair decisions.
4. LOCAM4. An Army logistics support cost model.
5. GEMM. An Army repair-level analysis model for electronic systems.
6. L-COM. An Air Force base activity simulation model.
7. AEP. An Air Force simulation model for assessing hardware performance and reliability (Ref 2:5).

The report recommended that the "set of models be made available in a computer framework which allows interactive, iterative and consistent application (Ref 2:5)."

Statement of the Problem

The primary conclusion of the SCALE investigation was that there exists a need to make the models proposed for integration more useable (Ref 2:60). One requirement would be a guideline on the combined use of the models to synergistically access the best features. In addition, a compatible set of input data variables is needed to resolve the current inconsistencies from model to model (Ref 2:61).

The problem that has been circumscribed by the foregoing discussion is to develop an integrating procedure along with associated software and guidelines that would validate at least a portion of the SCALE proposal. The attempt needs to assess factors which might cause differences in the before and after use of the models. In addition, the research would need to survey the implications of using an integrated framework.

Scope

One overriding concern in this study was the level of involvement that would be required to implement the SCALE proposal in toto. It was decided to restrict the scope to certain aspects of the SCALE proposal and to three models: LSC, ORLA and MOD-METRIC. The Army models, LOCAM⁴ and GEMM were excluded because they have not, as yet, received wide attention in the Air Force; and consequently, the computer incompatibility and lack of experience in using these models became overruling considerations. By contrast, a great deal of expertise was available for the Logistics Composite Model (L-COM) and the Avionics Evaluation Program (AEP). However, the disqualifying factor here was the complex formatting of the data inputs for these simulation packages. In addition, there is very little overlap with the other five models in data requirement and mode of application (Ref 2:37-40).

The three models chosen have certain attributes which make them attractive for a first attempt at integration. In particular,

1. They are Air Force developed models which have been computerized on the time-sharing CREATE system maintained by the Air Force Logistics Command.
2. They are used routinely in the acquisition process in AFLC.
3. Comprehensive user's guides have been developed for each model.

The fundamental purpose of the Logistics Support Cost (LSC) model is to estimate the expected support costs that may be incurred by adopting a particular design (Ref 12:3). As such, LSC is the basic AFLC tool to support the early phases of logistics acquisition management and the logical choice for initiating the development of a SCALE framework. Of the candidates proposed for SCALE integration, the

Optimum Repair-Level Analysis (ORLA) and MOD-METRIC models have both intuitive and practical appeal for inclusion in an investigation of an interface procedure. The LSC model requires data of a level of repair and inventory nature; and it follows that the more detailed analyses of the ORLA and MOD-METRIC models in these areas may enhance the predictive abilities of LSC.

In brief, the scope of the remainder of this study will focus on making ORLA and MOD-METRIC decision indicators compatible with LSC input requirements.

Methodology

To investigate the problem within the scope that has been set forth, the research centers on two requisites:

1. A procedure for transforming variables into inputs accessible by any of the models.
2. A scheme which defines how each model iteratively interacts with the others.

In Chapter V the study describes the respective roles of the models within the ILS concept by detailing their individual methodologies and analytic techniques. The basic material is taken from the following guides:

1. "Logistics Support Cost Model User's Handbook", AFLIC/AQMLE, Wright-Patterson AFB, OH, June 1975.
2. "Optimum Repair-Level Analysis (ORLA)", AFLCM/AFSCM 800-4, Department of the Air Force, June 1971.
3. "MOD-METRIC: A Multi-item, Multi-echelon, Multi-indenture Inventory Model", Muckstadt, J. A. and J. M. Pearson, AFIT School of Systems and Logistics, Wright-Patterson AFB, Ohio, February 1976.

Chapter VI begins with an analysis of differences in input variables and assumptions associated with the models. This review was initiated in the Battelle report on the SCALE proposal (Ref 2:19-35).

Next, a computer-compatible input routine is developed which transforms static variables into a data array available to the three models. The use of all three models currently requires approximately 170 variable definitions which share a common base. Because of considerable overlap, this total can be reduced by about one third thru a transformation routine accessible to all models simultaneously.

The interaction of the models is discussed in Chapter VII, along with a scheme to interface the analytical methods so that an iterative procedure results. In subsequent discussion of tailoring the models to achieve some level of interaction it should be noted that "interactive" is used in this study to connote the manner in which the individual models interrelate; not in the more frequent context of using the models in an "on-line" computer terminal sense. Chapter VII does rely heavily, though, on the FORTRAN-based computer listings of the models which are available on AFIC's CREATE computer operating system.

The concluding chapter of this study is devoted to assessing the outcome of this first attempt (by the researcher) at model integration. It lays out the assumptions and frequent simplifications that were required to investigate, in a small way, the broad area of logistics acquisition modelling.

Chapter V

The LOGISTICS SUPPORT COST, OPTIMUM REPAIR- LEVEL ANALYSIS and MOD-METRIC Models

The three models described in this chapter enable acquisition managers to perform detailed analysis of the effectiveness and cost factors associated with logistics support for new systems. The LSC and ORLA models have been used for some time by logistics program managers (DPML's) and system contractors during the design selection process. The MOD-METRIC program, a more recent development, has received its widest application at the headquarters AFIC and subordinate Air Logistics Center levels.

The descriptions which follow focus on the underlying assumptions, data requirements and analytical methods of the models. Their modes of application and roles in the acquisition cycle will be discussed in conjunction with the material in the next two chapters.

The LOGISTICS SUPPORT COST Model

The LSC model is one of the methods used to estimate the expected support costs incurred by adopting a particular design (Ref 12:3). The model employs cost accumulating techniques --- that is, it arrives at its final estimates by summing standard and projected cost elements over the life cycle of a system. Its comparison of design alternatives is characterized by cost precision rather than cost accuracy. This may appear to be counterproductive to the intent

of life cycle costing; but as the reader will recall from Chapter III, absolute cost estimates are diminished by the uncertainty of predicting the future. Instead, LSC focuses on precision of cost differences among systems to exploit the merits of making comparisons based on relative cost. The model is useful in three areas:

1. Source selection --- To obtain an estimate of differential costs among proposed design configurations.
2. Contract definition --- To establish a baseline commitment on aspects of operational supportability pending verification.
3. Prototyping --- To aid decisions in discriminating among design alternatives (Ref 12:4).

Assumptions. The characteristics of the operating environment envisioned in LSC are important to understanding the scope of the cost estimates which result. The following assumptions form the basis for the simplified view of the world which LSC models:

1. A uniform level of activity (such as flying hours) exists at each operating location.
2. The spares stock level and pipeline quantities are computed to support end strength levels of activity.
3. Only those logistics support costs associated with the weapon system, major subsystem and First Line Unit (FLU) are explicitly computed. Components below FLU are considered in terms of FLU repair costs (Note: subsystem and FLU are differentiated in the List of Abbreviations at the beginning of this study).
4. There is one depot repair location and any specified number of intermediate (base-level) repair locations.
5. The required quantity of support equipment (SE) is determined for peak activity. In addition, the calculation for required amounts of identical SE is predicted on the man-hours required to perform the tasks. In other words, at peak activity a single piece of SE will be occupied for the entire time it takes a man to complete the task. If identical tasks are being performed concurrently, additional SE will be required.
6. Estimates for initial maintenance cadre training costs are also applied to follow-on (government sponsored) training.

7. Certain non-quantifiable costs are not considered. Examples are modification costs, maintenance costs generated by false removals, and replacement of items condemned at depot as a result of policy. These elements contribute to LCC, but cannot be attributed to selection of any particular design. Therefore, even if they could be quantified, there is no equitable way to distribute them among competing designs (Ref 12:5-6).

Data. There are 94 data elements required to satisfy the model equations. 36 are standard elements pertaining to the weapon system in general. The rest require multiple definition, depending on the number of systems, FLUs or pieces of support equipment being considered.

For descriptive purposes, the source and type of data can be divided into five categories:

1. Program elements --- These elements are derived from the design and operational concept of the system. Some examples are: projected flying hours, geographic deployment and weapon system standards. They are normally provided by the government.

2. Contractor-furnished system elements --- These are costs at major system level which accrue to a particular developmental design.

3. Contractor-furnished FLU elements --- These costs are derived from operational experience with previous system components or contractor projections for items incorporating new technology.

4. Propulsion system elements --- The contractor supplies these estimates based on engine unit cost and characteristics. The government provides inputs such as repair cycle time, resupply time and fuel costs.

5. Government-furnished standard elements --- These are historical cost and time figures for labor, inventory, pipeline time and the like (Ref 12:6-7).

Model design. The LSC model consists of ten equations or submodels, each representing a resource cost element necessary to operate the logistics system (Ref 12:8). The ten equations are:

1. Cost of FLU Spares.
2. On-Equipment Maintenance.
3. Off-Equipment Maintenance.
4. Inventory Management Cost.

5. Cost of Support Equipment.
6. Cost of Personnel Training.
7. Cost of Management and Technical Data.
8. Cost of Facilities.
9. Cost of Fuel Consumption.
10. Cost of Spare Engines.

Equations 1 thru 8 represent individual cost centers which contribute to the life cycle cost of a system. Equations 9 and 10 concern costs unique to propulsion systems --- kept separate for the sake of visibility. The net product of the LSC computations is determined by aggregating the results of the individual equations for each system being considered.

Figure 1 shows the LSC equation for Cost of FLU Spares. It is representative of the types of mathematical techniques used by LSC. The total cost, in this case, is separated into three components: cost of spares to fill the intermediate pipeline, cost to fill the depot repair pipeline and cost to replace condemned FLUs.

The first term computes cost to fill the intermediate (base) repair pipeline at peak level of activity. STK_i represents the number of FLU spares of the i^{th} type required for each base plus a safety stock. Since STK_i is not provided as raw data, it is calculated by a subsystem of equations which consider the average demand rate (Eqn 1.1) and the time in the pipeline (Eqn 1.2) against the standard set for expected backorders, EBO. The product of λ_i and t_i represents the number of demands for a specific type of FLU expected to occur while the FLU is in the base repair pipeline. Because these demands occur in a random manner, it is necessary to make a probabilistic estimate of demand to provide a reliable level of safety stock. In this example, the probability of a demand occurring given a mean demand, $\lambda_i t_i$, is assumed to follow a Poisson distribution. This distribution

C_1 = Cost of FLU Spares

$$\begin{aligned}
 &= M \sum_{i=1}^N (STK_i)(UC_i) \\
 &\quad + \sum_{i=1}^N \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)(NRTS_i)(DRCT_i)}{(MTBF_i)} (UC_i) \\
 &\quad + \sum_{i=1}^N \frac{(TFFH)(QPA_i)(UF_i)(1-RIP_i)(COND_i)}{(MTBF_i)} (UC_i)
 \end{aligned}$$

$$\begin{aligned}
 \lambda_i &= \text{Demand rate per base} \\
 &= \frac{(PFFH)(QPA_i)(UF_i)(1-RIP_i)}{(M)(MTBF_i)} \quad (1.1)
 \end{aligned}$$

$$\begin{aligned}
 t_i &= \text{pipeline time} \\
 &= (RTS_i)(BRCT_i) + (NRTS_i) [(OSTCON)(1-OS) + (OSTOS)(OS)] \quad (1.2)
 \end{aligned}$$

$$\text{Minimize } STK_i \text{ such that } \sum_{x > STK_i} (x - STK_i) p(x | \lambda_i t_i) \leq EBO \quad (1.3)$$

where:

- M - number of bases
- STK_i - FLU spares required to fill base repair pipeline (stock).
- UC_i - unit cost at original provisioning.
- PFFH - peak force flying hours/month.
- QPA_i - quantity of identical FLUs in system (Quantity Per Application).
- UF_i - ratio of operating hours to flying hours (Use Factor).
- RIP_i - fraction of failures which can be repaired in place.
- $NRTS_i$ - fraction of removals returned to depot (Not Repairable This Station).
- $DRCT_i$ - average depot repair cycle time.
- $MTBF_i$ - mean (operating) time between failures.
- TFFH - total force flying hours.
- $COND_i$ - condemnation rate.
- RTS_i - fraction repairs at base level (Repairable This Station).
- $BRCT_i$ - average base repair cycle time.
- $OSTCON_i$ - average order-and-ship time - CONUS.
- $OSTOS_i$ - average order-and-ship time - overseas.
- OS - fraction of force deployed overseas.

Fig. 1. LSC Model Equation (Adapted from Ref 12:2-1)

is appropriate in many situations where an "event" occurs over a period of time; when it is as likely to occur in one interval as any other; and where the occurrence of an event has no effect on whether or not another occurs (Ref 13:318). The "event" in this case is a demand for a specific FLU. Using this condition, the minimum STK_i can be chosen consistent with the expected (planned) number of demands that will be unfilled as a matter of policy (EBO). The mathematical representation of this procedure is shown in Eqn 1.3 of Figure 1. Finally, the cost to fill the base pipeline is computed by multiplying the quantity, STK_i , times the unit cost, UC_i , and summing over all types of FLUs from $i = 1, \dots, N$. The result is then multiplied by the number of bases, M , to determine total cost.

The second and third terms of the cost equation for FLU spares have the same basic structure as the first. There are two differences that make them more computationally palatable, however. First, the raw input data is directly substituted, obviating the need for a system of sub-equations. And, there are no probabilistic considerations thus simplifying the calculations.

Summary. The remaining 9 equations in the LSC model are similar to the one just described. The predominant analytical method is the cost accumulating equation. In 7 of the ten equations, Mean (operating) Time Between Failures (MTBF) appears as the basic reliability parameter of the FLU. An important factor to consider when using LSC is the weight this variable, usually an engineering estimate, carries when making weapon system comparisons. Another technique used by LSC is the probabilistic estimate --- such as the one based on the Poisson distribution in the equation described above.

Although applied with equal effect across the systems being compared, the more important consideration is the degree of correspondence that the hypothetical underlying distribution has to the actual operating environment.

Because this study focuses on the computerized version of the LSC model, further description of the model equations will not be made. A mathematical description of all ten equations can be found in Appendix 3 of the Logistics Support Cost Model User's Handbook, published by AFLC/AQM.

The OPTIMUM REPAIR-LEVEL ANALYSIS Model

Optimum repair-level analysis is an iterative process designed to be used by logistics managers throughout the validation, development and production phases of a weapon system life cycle (Ref 14:1-1). The concept of level of repair encompasses not only the repair location but the extent of maintenance permitted and the resources necessary to support the repair policy. Repair in this sense includes the identification of items to be supported under a discard-at-failure maintenance policy.

The mathematical ORLA model provides a decision indicator of the optimum maintenance policy which will help achieve the minimum total support cost for a specified level of system effectiveness. It can be described as a two-echelon, single item, single indenture process. The model's analytic method relies, as does LSC, on the cost accumulating equation. It computes a discard penalty (cost), intermediate (base) repair penalty and depot repair penalty for the system life cycle; then selects the penalty with the lowest cost. The computerized version of the model also produces a summary of

required support equipment and performs a stepwise sensitivity analysis on selected variables while all others are held constant.

Assumptions. Many of the assumptions underlying the ORLA model are identical to those stated for LSC. In particular, those relating to the view of the operating environment such as uniform levels of activity at each base, computing quantities based on end strength and a two-echelon (depot and base) maintenance policy are the same. ORLA makes the following additional assumptions about the maintenance structure:

1. The cost of items to support a discard-at-failure option is a front-end investment. The quantity is only a "best estimate" because it is made early in the acquisition process and, consequently, the initial procurement may not accurately reflect what is actually used during the system's life cycle.
2. The model considers only one indenture of the item being analyzed. That is, it considers the quantity of the item being analyzed; and the quantity of lower indenture repairable or economic order quantity items required for repair of the item analyzed.
3. Since the decision on lower indenture items (ie., repairable or EOQ) is not usually known when the model is run for specific analysis items, the stockage of lower indenture items is computed using a modification to existing EOQ formula and, consequently, the model tacitly assumes discard of these lower indenture items.
4. The quantity and cost of repair materials (lower indenture components and supplies) for each required repair action is assumed to be the same at intermediate and depot level.
5. A depot-level safety stock is established to account for the increase in serviceable items stocked when a decision to repair a certain item at depot is made. It is set at 15 times the depot daily demand rate for the item in accordance with AFM 57-1.
6. The cost formulations assume that the items in the repair pipeline and stockage of end items and spare parts are an investment which accrue in entirety to the maintenance decision selected. The level of this investment should consider an appropriate discount factor to account for the time-value aspects of procuring spare parts during the system life cycle in contrast to the discard option's front-end investment.

7. The model assumes that any failure generated within the system's life cycle will process through a complete maintenance cycle. This means that in setting stock levels, it is highly probable that some reparable items will be in the pipeline or stockpile when the system's life cycle terminates; however, full costs for procuring and repairing these assets will be charged to the system (Ref 14:2-12 thru 2-17).

Data. There are 68 data elements required to initiate the ORLA model.

An additional 9 are required if the support equipment summary is used.

The input requirements are divided into three categories:

1. Standard data elements --- These are constant values for a given ORLA application; 36 required.

2. Item data package --- This is composed of three types of inputs; Item description, Maintenance factors and Variable data parameters; 32 required for each FLU.

3. Support Equipment data set --- This is an optional set. There are two types of entries: Intermediate/Depot support equipment description; and identity of items requiring support equipment; 9 required.

The computer version of ORLA will perform repair-level analysis on a maximum of 100 items during a run (Ref 15:1-2).

Model design. The ORLA model is made up of three sets of cost accumulating equations; each set dealing with one of the maintenance policy options. The categories and their defining equations are:

1. Discard at Failure Cost: T

- T₁ = Life cycle replacement cost
- T₂ = Replacement packing and shipping cost
- T₃ = Base stock level cost --- discard option

2. Repair at Intermediate Cost: F

- F₁ = Field shop support equipment cost
- F₂ = Field shop support equipment maintenance cost
- F₃ = Intermediate Technical data cost
- F₄ = Intermediate-level training cost
- F₅ = Base stock level cost --- intermediate repair
- F₆ = Intermediate repair labor cost
- F₇ = Intermediate packing and shipping cost
- F₈ = Field supply administration cost
- F₉ = Intermediate repair facilities cost
- F₁₀ = Repair materiel cost
- F₁₁ = Cost of introducing items into the Air Force inventory

3. Repair at Depot Cost: D

- D₁ = Depot repair pipeline cost
- D₂ = Depot support equipment cost
- D₃ = Depot support equipment maintenance cost
- D₄ = Depot technical data cost
- D₅ = Depot-level training cost
- D₆ = Depot packing and shipping cost
- D₇ = Depot safety stock level cost
- D₈ = Base stock level cost --- depot repair
- D₉ = Depot repair labor cost
- D₁₀ = Depot repair facilities cost
- D₁₁ = Repair materiel cost
- D₁₂ = Cost of introducing items into the Air Force inventory

The form of the defining equations is similar to the method described for the LSC model with one exception. The ORLA model does not make use of probabilistic techniques in determining the distribution of demands for a reparable item. This is due in part to the nature of the support cost problem that ORLA evaluates. The ORLA objective is to estimate costs for the three prospective maintenance policies. In this context, demand distributions are not decisive factors because the same failure rates (and hence, demand for replacements) can be expected no matter which maintenance policy is adopted. Instead, ORLA uses point estimates or percentages in those cases where demand rates must be considered. The mathematical descriptions of the equations can be found in Attachment 3 of AFLC Manual 800-4, dated 25 June 1971.

One area of the ORLA model somewhat related to the demand situation is the determination of the expected number of times per month a task which requires corrective action will occur. This quantity is titled: Questionable Corrective Task Frequency (QCTGM). QCTGM is an important variable in ORLA; appearing in 17 of the 26 equations. Its calculation is shown in Figure 2.

The most critical component of the QCTGM calculation is the factor involving mean time between corrective tasks for the item

QCTGM = Questionable (Expected) Corrective Task Frequency

$$= \frac{(UE)(UR)(\theta)(QPA)}{(MTBCT)}$$

MTBCT = Mean time between corrective tasks for an item

$$= \frac{(MTBF)}{(K_{1,2})(K_3)(1-K_4)}$$

where:

- UE - unit equipment per operating location.
- UR - utilization rate.
- QPA - quantity of like items per unit equipment.
- θ - Failure allocation. The failure allocation is the reliability apportionment assigned to the next lower indenture of equipment. It is the proportion of failures of the item being analyzed caused by failure of a specific component part.
- $K_{1,2}$ - Conversion factors for realigning specification MTBF to operating environment.
- K_3 - Ratio of item operating hours to flying hours.
- K_4 - Percentage of failures which can be corrected on-equipment.

Fig. 2. Questionable Corrective Task Frequency
(Adapted from Ref 14:2-11)

(MTBCT). This element is a variant of MTBF. MTBF, which is usually a design estimate, can be deflated by any or all of the K-factors as shown in Figure 2. $K_{1,2}$ will normally equal 1 because the MTBF used should be the minimum acceptable value for the applicable configuration item specification. However, the ORLA formulation does allow the user to amend the MTBF figure based on "more realistic" estimates such as Reliability Qualification Testing (AFIC Manual 66-18) or operational experience.

Summary. The ORLA model's final estimates of repair-level cost are made by summing the individual cost equations under the three categories and then selecting the least cost solution. In addition to the support equipment summary which is included in the computer-based model, a sensitivity analysis is also performed. This analysis traces the effect on the repair-level decision of variation in seven standard factors:

1. Unit equipment per operating location.
2. Utilization rate.
3. Direct labor hours to fault isolate, repair and verify per repair task.
4. Unit cost.
5. Mean time between demands.
6. Cost of unique depot support equipment.
7. Cost of unique intermediate support equipment.

The user can add three additional sensitivity candidates. In conducting the sensitivity analysis each factor is varied from 20% to 500% of its original value while all others are held constant. If a reversal signalling change in repair decision occurs, this fact and the cost figures surrounding the new decision are printed out.

The fact that the ORLA model considers only one indenture has already been mentioned. This requires that the user either initiate

an ORLA at the lowest indenture level and work up to system level; or, if circumstances require, start at or near system level and recognize that the model enforces a discard-at-failure and subsequent EOQ decision for lower indenture. In the latter case, the techniques used by the model for establishing EOQ should be examined to insure that they reflect realistic policy considerations.

The MOD-METRIC Model

The MOD-METRIC model is an outgrowth of the Multi-Echelon Technique for Recoverable Item Control (METRIC) developed by the RAND Corporation. Both METRIC and MOD-METRIC have as their objective the determination of stock levels in a two-echelon (base and depot) inventory system for items that are subject to repair when they fail. The MOD-METRIC model differs in that it explicitly considers the existence of a hierarchical parts structure (Ref 16:1). That is, a system where individual, sometimes reparable, components are subordinate to a larger assembly which is the smallest object normally removed from a weapon system as a unit. The algorithm used to calculate the stock levels (spares provisioning) uses the concept of marginal analysis to allocate a given level of investment in the manner which achieves the greatest reduction in backorders for an item.

The MOD-METRIC model is the most analytically "elegant" of the three models discussed in this chapter. It is based on probability estimates of demand and classical optimization techniques rather than the cost accumulating methods used in LSC and ORLA. Of course, the model serves an entirely different purpose from life cycle cost estimation; it proceeds from a given level of cost to predicting

the quantity and distribution of spare parts required for an optimum inventory policy.

Assumptions. The assumptions which follow apply to both the METRIC and MOD-METRIC versions of the model. The overall view of the operating environment is similar to that envisioned by LSC. However, the approach to modelling the demand process is more markedly thorough than either LSC or ORLA. Assumptions:

1. A particular item may be demanded from any one of several operating locations; these "bases" are supplied from a single depot location.
2. Maintenance time includes the time required to fault isolate, remove, replace and test a defective module.
3. Resupply time is the time it takes to replace an asset that was demanded from base supply.
4. A backorder occurs when there is an unsatisfied demand at base level. The daily expected number of backorder days is calculated by dividing the accumulated backorder days by the number of days in the data period and then determining the mathematical expectation of the quantity.
5. No penalty is directly assessed for depot backorders except as they affect base backorders.
6. The probability distribution associated with the demand process is assumed to be a compound Poisson distribution. (This is discussed further under Model design). In addition, the distribution of demand is stationary, which means that the process does not depend on any particular starting point in time, but rather on the time interval between demands (Ref 17:329).
7. There is no lateral resupply among bases.
8. There are no condemnations in the repair pipeline. All failed items which enter the repair cycle are assumed to be successfully repaired at base or depot. In addition, as soon as an item fails it is immediately placed in the repair pipeline; no batching occurs.
9. The quantity of spare assets at a base remains constant over time. Stock on hand (serviceable and unserviceable) plus on order from depot minus backorders equals spare assets.

Data. The MOD-METRIC model requires various data inputs, although not as many as either LSC or ORLA. The necessary parameters include average base and depot repair times for each item, unit costs, NRTS rates, and average order-and-ship times (Ref 16:6). The single most important parameter is the probability distribution associated with the demand process. Several possibilities exist for choosing a demand distribution, however, the MOD-METRIC model utilizes a Poisson variate suggested by Craig Sherbrooke of the Rand Corporation. This distribution is discussed in the next section.

Model design. The MOD-METRIC objective is to minimize the expected base backorders for an item subject to an investment constraint on the total dollars allocated for that item and its components (Ref 16:22). The calculation for expected base backorders is derived from the theory of the infinite channel queuing model. This model is applicable to systems which operate under an inventory policy where spare assets at a base remain constant over time. In essence, the queuing model uses the probability distribution of demand to specify the probability distribution for the number of assets in supply which, in turn, is used to calculate the expected number of backorders (Ref 16:10). The MOD-METRIC model uses a compound Poisson distribution to describe the demand pattern. From this a negative binomial distribution emerges as the distribution of the number of assets in supply.

Using the measure of expected backorders derived from the above distributions and average resupply time, which is also assumed to be compound Poisson, an algorithm to calculate stock levels by using marginal analysis can be described. The mathematical problem which must be solved is shown in Figure 3. The solution requires that the

$$\text{Min } \sum_{i=1}^M \sum_{x_i = s_i + 1} (x_i - s_i) p(x_i / \lambda_i T_i)$$

$$\text{subject to } \sum_{i=1}^M (C_e S_i + \sum_{j=1}^N C_j S_{ij}) + \sum_{j=1}^N C_j S_{oj} + C_e S_o \leq C$$

Where:

M - number of bases.

S_i - end item stock level at base i.

λ_i - removal rate for end item at base i.

T_i - average resupply time for end item at base i.

C_e - unit cost of end item.

N - number of sub-modules.

C_j - unit cost of module j.

S_{ij} - module j stock level at base i.

S_{oj} - module j stock level at depot.

S_o - end item stock level at depot.

C - budget limit.

Fig. 3. Stock Level Algorithm
(Adapted from Ref 16:25-26)

problem be partitioned, and separate optimizations be performed for end items and sub-modules. First, the sub-module problem is solved by constructing a LaGrange multiplier function and solving N independent module subproblems for a given value of the LaGrangian multiplier. As each subproblem is solved, the quantity of depot module stock is fixed and another optimization is conducted to determine base stock by using marginal analysis. Optimal depot stock can then be calculated using an adaptive search procedure to find the value of the multiplier that is most closely associated with the budget constraint. The result is an allocation of the budget among depot and base module stock levels. The portion of the problem concerning end items can then be solved in the same manner using that part of the budget not allocated to modules in the first step of the algorithm.

Summary. It is apparent that in solving the minimization problem for end items and sub-modules, a great deal of brute force analysis is required. Operational experience with the model has shown that the search for optimal depot stock rarely exceeds ten applications for either end items or sub-modules (Ref 16:28). In addition, the number of module budgets that need to be evaluated is limited because of the narrow range assumed by the LaGrangian multipliers.

The MOD-METRIC algorithm described applies to a single Line Replaceable Unit (LRU) and its subordinate Shop Replaceable Units (SRU's). In the computer version of the model, this algorithm is extended to solve problems in which many LRU/SRU groupings are considered simultaneously. The objective of this extended model is to minimize total expected base LRU backorders subject to a

constraint on investment in all LRU and SRU's. A detailed description of this process can be found in "MOD-METRIC: The Algorithm and Computer Programs", by John A. Muckstadt and John M. Pearson.

Chapter VI

A Model Compatible Input Routine

The logistics models described in the previous chapter --- LSC, ORLA and MOD-METRIC --- contain considerable overlap in input data requirements. It is generally true to say that all three models use the same data base. In the analysis of a specific system, the differences in input data from one model to the next are primarily due to the level of detail and level of data aggregation that is required. Of course, because of the differing aspects of logistics acquisition addressed by the models, there are also certain unique data elements required for individual model implementation.

With the help of tables, this chapter attempts to lay out the relationships among the specific input variables in the models.

The required variables are divided into three categories:

1. Common variables. These are input elements that are identical in at least two of the models. The only differences may occur in the variable names assigned to them.
2. Unique variables. These elements are unique to the requirements of a specific model and consequently are not considered by the other models.
3. Aggregate variables. These data elements exist in more than one model but differ in level of aggregation or unit of measurement.

The arrangement of the tables follows the method initiated in the Battelle study. The variables are listed according to model under the major subheadings: Weapon System, Maintenance, Personnel, Spares, Support Equipment, and Logistics Administration. The

description of the variables in the first column gives an insight to the scope and assumptions underlying the respective model.

The final segment of this chapter describes the collation of input data to form a single list which is compatible with the requirements of the three individual models.

Common Variables

The 15 variables which are common to at least two of the models are shown in Table II. Variable dimensions (where applicable) are shown in parentheses next to the specific variable name. The descriptions under "Input Data Items" generally follow the definitions given in the Battelle SCALE report (Ref 2:19-35). More detailed explanations of the variable definitions can be found in References 12, 15 and 18.

Unique Variables

There are 51 variables which serve a unique requirement in application of the models. These are listed in Table III. The largest portion (39, to be exact) are unique to the LSC model. This occurs for two reasons. First, LSC generally requires a greater level of detail since it attempts to deal with total life cycle cost in all logistics areas. This generates the requirement for additional data elements --- many in the area of man-hour accounting. Second, LSC is the only model which separates and analyzes engines as distinct entities. Thus, engine peculiar data makes up a large part of the unique variable list.

Aggregate Variables

The term aggregate variables is used to designate those

Table II
COMMON VARIABLES

Input Data Items	LSC	ORIA	MOD-METRIC
A. Weapon System			
1. Number of operating locations	M	N	NBASES
2. Operational service life of system	PIUP(years)	PIUP(years)	
3. Quantity of like FLUs within the parent system	QPA	QPA	APP
4. Expected unit cost of FLU	UC (\$)	UC (\$)	CLRU (\$)
5. Ratio of operating hours to flying hours for the FLU (Use Factor)	UF	K_3	
6. FLU unit weight	W (lb)	UW (lb)	
B. Maintenance			
1. Mean time between failures	MTBF(hours)	MTBF(hours)	
2. Fraction of removed FLUs expected to be returned to depot for repairs	NRTS		YNRTS
C. Personnel			
1. Annual turnover rate for base personnel	TRB	VF	
2. Annual turnover rate for depot personnel	TRD	VD	
D. Spares			
1. Fraction of removal FLUs expected to be condemned at base level	COND		CONL
E. Support Equipment			

Table II (Continued)

Input Data Items	LSC	ORLA	MOD-METRIC
F. Logistics Administration			
1. Annual base supply line item inventory management cost	SA (\$/item/yr)	SA (\$/item/yr)	
2. Number of new "P" coded repairable assemblies within the FLU	PA	LA	
3. Number of new "P" coded consumable items within the FLU	PP	LP	
4. Average cost of tech- nical documentation (does not include reproduction)	TD (\$/page)	TD (\$/page)	

Table III
UNIQUE VARIABLES

Input Data Items	LSC	ORLA	MOD-METRIC
A. Weapon System			
1. Unit equipment per operating element		UE	
2. Peak force flying hours	PFFH(hrs/mo)		
3. Number of systems within the weapon system	NSYS		
4. Number of different FLU's within the system	N		
5. Number of engines per aircraft	EPA		
6. Expected unit cost of a whole engine	EUC (\$)		
7. Fuel cost per engine	FC (\$/gal)		
8. Fuel consumption rate of one engine	FR (gal/hr)		
9. Weight of repair material per repair task		SW (lb)	
B. Maintenance			
1. Average engine operating hours between removals	CMRI (hrs)		
2. FLU operating environment conversion factor		K_1, K_2	
3. Mean time between demands			YMTBD (hrs)
4. Fraction of removed whole engines which must be returned to depot for repair	ENRTS		
5. Average man-hours per failure to complete off-equipment maintenance records	MRF (hours)		
6. Average man-hours per failure to complete on-equipment maintenance records	MRO (hrs.)		

Table III (Continued)

Input Data Items	LSC	ORLA	MOD-METRIC
B. Maintenance (cont.)			
7. Average man-hours per failure to complete supply transaction records	SR (hrs)		
8. Average man-hours per failure to complete transportation transaction records	TR (hrs)		
9. Average man-hours to perform shop fault verification on a removed FLU	BCMh (hrs)		
10. Average man-hours to perform corrective maintenance on the FLU in place	IMH (hrs)		
11. Average man-hours expended to gain access to the FLU in place	PAMH (hrs)		
12. Average man-hours to fault isolate, remove and replace entire FLU	RMH (hrs)		
13. Average man-hours to remove and replace a whole engine	ERMH (hrs)		
14. Fraction of original unit cost for depot overhaul of engine including labor and consumable material consumption	EOH		
15. Average man-hours to perform a scheduled periodic or phased inspection of system	SMH (hrs)		
16. Fraction of removed FLU's which can be repaired or replaced in line	RIP		
17. Ratio of removals to failures		K_4	
18. Interval between scheduled periodic or phased inspections	SMI (hrs)		

Table III (Continued)

Input Data Items	LSC	ORLA	MOD-METRIC
C. Personnel			
1. Cost of peculiar training equipment required for the system	TE (\$)		
2. Number of depot personnel to be trained per supported location		X	
3. Number of base personnel to be trained per location		W	
D. Spares			
1. Expected number of unfilled demands existing at any base at any point in time	EBO		
2. Procurement lead time			PLT (months)
3. Engine automotive resupply and build-up time	ARBUT (mos)		
4. Base engine repair cycle time	BP (mos)		
5. Probability of satisfying a random demand for a whole engine from reserviceable stock (base)	CONF		
6. Depot engine repair cycle time	DP (mos)		
7. Number of stockage locations for spare engines	LS		
E. Support Equipment			
1. Total cost of additional common base shop support equipment per base	BCA (\$/base)		
2. Same as item 1 for depot SE	DCA (\$)		
3. Total cost of peculiar flight line SE and additional common flightline SE	FIA (\$/base)		

Table III (Continued)

Input Data Items	LSC	ORLA	MOD-METRIC
E. Support Equipment (cont.)			
4. Total cost of shop equipment per base not directly related to repair of the FLU	BPA (\$/base)		
5. Same as item 4 for depot	DPA (\$)		
6. Combined utilization rate for all like items of support equipment, base level	BUR		
7. Same as item 6 for depot	DUR		
8. Fraction of downtime for a unit of SE for maintenance and calibration	DOWN		
9. Number of line items of peculiar shop support equipment used in repair of the FLU	K		
F. Logistics Administration			
1. Number of standard (already stocked) parts within the FLU which will be managed by a base for the first time	SP		
2. Ratio of packaged to unpackaged weight - CONUS		PWRCON	
3. Ratio of packaged to unpackaged weight - OS		PWROS	
4. Investment items for which air movement of replenishment items is planned is identified as Airlift = 0. Surface transportation is Non-airlift = 1		AIR/NONAIR	
5. Prime Air Logistics Center			ALC

variables which share similar definitions, but require minor transformation to fit the exact requirements of a specific model. Table IV shows the 51 variables in this category. By aggregation and/or change of dimension, this list can be reduced to 43 input variables which satisfy the requirements of the three models for specific data. The input variables are shown in the first column under the Input Data Items for the models. Next to the input variables, the transformation which makes them compatible with individual models is shown.

Description of the Input Routine

The input routine developed to establish a common data base for the three models is best described as a "front-end" package for the three distinct models. It is adapted for use with the computerized versions of the LSC, ORLA and MOD-METRIC models as they currently exist on the AFLC CREATE operating system. Two points in this arrangement should be noted at the outset. First, only the input phase is affected by the routine discussed in this study. Nothing is done to alter the actual model workings or output formats as they currently exist. Second, although the input routine and the models can be accessed directly via CREATE remote terminal, only the LSC model is truly interactive in a time-shared sense allowing output to be printed at the terminal. Both ORLA and MOD-METRIC utilize line printer equipment in the batch mode for output. Further description and use of the models on the CREATE system can be found in Appendix B of this study and the respective model user's guides (Refs 12, 15 and 18).

Table IV
AGGREGATE VARIABLES

Input Data Items	LSC	ORLA	MOD-METRIC
A. Weapon System			
1. Fraction of total force deployed overseas	OS		
2. Fraction of total force deployed in CONUS		CON	
input variable: OS		CON = 1 - OS	
3. Total force flying hours	TFFH(hrs)		FH(K)
4. Unit equipment utilization rate		UR(fly hrs/ mo)	(Fly/hrs month/base)
input variable: UR	TFFH= (UR)(PIUP)(12)		FH(K) = $\frac{UR}{M}$
B. Maintenance			
1. Fraction of removed FLUs expected to be repaired at base level	RTS		
input variable: NRTS	RTS=1-NRTS		
2. Average man-hours to perform base level maintenance on removed FLUs	BMH(hrs)		
3. Same as item 2 for depot	DMH(hrs)		
4. Direct labor man-hours to fault isolate, repair and verify per task		RMH (hrs)	
input variables: BMH, DMH		RMH = $\frac{BMH+DMH}{2}$	

Table IV (Continued)

Input Data Items	LSC	ORLA	MOD-METRIC
B. Maintenance (cont.)			
5. Base consumable material consumption rate	BMR(\$/repair hr)		
6. Cost of repair materials per repair task		SC (\$)	
input variable: SC	$\text{BMR} = \frac{\sum \text{SC/BMH}}{\text{NSYS}}$		
7. Same as item 5 for depot	DMR (\$/repair hr)		
input variable: SC	$\text{DMR} = \frac{\sum \text{SC/DMH}}{\text{NSYS}}$		
8. Fraction of FLU unit cost for stockage and repair of lower level assemblies at base level	BMC		
9. Same as item 8 for depot level	DMC		
10. Fraction of average repair costs comprised of known piece parts		PP	
input variables: BMC, DMC	$\text{PP} = \frac{\text{BMC} + \text{DMC}}{2}$		
C. Personnel			
1. Direct productive time at base level	PMB (hrs/man-yr)	FIA (hrs/man-wk)	
2. Available work time per man in the base shop	BAA (hrs/man-mo)		
input variables: PMB	$\text{BAA} = \frac{\text{PMB}}{11}$	$\text{FIA} = \frac{\text{PMB}}{48}$	

Table IV (Continued)

Input Data Items	LSC	ORLA	MOD-METRIC
C. Personnel (cont.)			
3. Same as item 1 at depot	PMD (hrs/man-yr)	DLA (hrs/man-wk)	
4. Same as item 2 at depot	DAA (hrs/man-mo)		
input variable: PMD	$DAA = \frac{PMD}{11}$	$DLA = \frac{PMD}{48}$	
5. Cost of peculiar training per man at base level	TCB(\$/man)	ZI (\$/man-wk)	
6. Duration of base level training		ZD (weeks)	
input variables: ZI, ZD	$TCB = \frac{\sum ZD}{NFLU} ZI$		
7. Same as item 5 for depot	TCD(\$/man)	YI(\$/man-wk)	
8. Same as item 6 for depot		YD(weeks)	
input variables: YI, YD	$TCD = \frac{\sum YD}{NFLU} YI$		
9. Base labor rate	BLR(\$/hr)	FLWR(\$/hr)	
input variable: BLR		$FLWR = \frac{\sum BLR}{NSYS}$	
10. Depot labor rate	DLR(\$/hr)	DLWR(\$/hr)	
input variable: DLR		$DLWR = \frac{\sum DLR}{NSYS}$	
D. Spares			
1. Average order and ship time within the CONUS	OSTCON(mo)		OST(K)(days)

Table IV (Continued)

Input Data Items	LSC	ORLA	MOD-METRIC
D. Spares (cont.)			
2. Same as item 1 for airlift investment items		OSTICON(mo)	
3. Same as item 1 for nonairlift investment items		OSTNCON(mo)	
input variables: OSTICON, OSTNCON	$\text{OSTCON} = \frac{\text{OSTICON} + \text{OSTNCON}}{2}$		$\text{OST(K)} = 15(\text{OSTOS} + \text{OSTCON})$
4. Average order and ship time to OS location	OSTOS(mo)		OST(K)
5. Same as item 4 for airlift investment items		OSTIOS(mo)	
6. Same as item 4 for nonairlift invest- ment items		OSTNOS(mo)	
input variables: OSTIOS, OSTNOS	$\text{OSTOS} = \frac{\text{OSTIOS} + \text{OSTNOS}}{2}$		$\text{OST(K)} = 15(\text{OSTOS} + \text{OSTCON})$
7. Base repair cycle	BRCT(mo)	BRT(mo)	BRTLRLU(days)
input variable: BRCT		$\text{BRT} = \frac{\sum \text{BRCT}}{\text{NFLU}}$	$\text{BRTLRLU} = \text{BRT}(30)$
8. Average depot repair cycle time	DRCT(mo)		DRTLRLU(days)
9. Depot repair pipe- line time		DPL(mo)	
10. Depot safety stock level time		DSS(mo)	
input variables: DPL, DSS for each FLU (i = 1, ..., NFLU)	$\text{DRCT} = \text{DPL}(i) + \text{DSS}(i)$		$\text{DRTLRLU} = \frac{\sum \text{DPL}(i)}{\text{NFLU}} + 30(\text{DPL}(i) + \text{DSS}(i))$

Table IV (Continued)

Input Data Items	LSC	ORLA	MOD-METRIC
E. Support Equipment			
1. Cost of software to utilize ATE	CS (\$)		
2. Cost of interconnecting hardware to utilize ATE	IH (\$)		
3. Cost of software and interconnecting hardware to utilize ATE at base level		ICS (\$/LRU)	
4. Same as item 3 for depot		DCS (\$/LRU)	
input variables: CS, IH for each LRU (i = 1, ..., NFLU)	CS = $\frac{\sum CS(i)}{NSYS}$ IH = $\frac{\sum IH(i)}{NSYS}$	ICS = DCS = CS(i) + IH(i)	
5. Cost of new base facilities to be constructed for operation and maintenance of the system	FB (\$/base)	FF (\$/LRU)	
input variable: FF	FB = $\frac{\sum FF}{(M)(NSYS)}$		
6. Same as item 5 for depot	FD (\$/sys)	DF (\$/LRU)	
input variable: DF	FD = $\frac{\sum DF}{NSYS}$		
7. Fraction of original cost to maintain base level SE	COB (%/yr)	FAR (%/FLU-yr)	
input variable: COB for each item of SE		FAR = $\sum COB$ for each FLU	

Table IV (Continued)

Input Data Items	LSC	ORLA	MOD-METRIC
E. Support Equipment (cont.)			
8. Same as item 7 for <u>depot</u>	COD(%/yr)	DMR (%/FLU-yr)	
input variable: COD for each item of SE		DMR = \sum COD for each FLU	
9. Cost per unit of peculiar shop support <u>equipment</u>	CAB(\$/unit)	IUA(\$/FLU)	
input variable: CAB for each unit of SE		IUA = \sum CAB for each FLU	
10. Same as item 9 for <u>depot</u>	CAD(\$/unit)	DUA(\$/FLU)	
input variable: CAD for each unit of SE		DUA = \sum CAD for each FLU	
F. Logistics Administration			
1. Initial management cost IMC(\$/item) to introduce a new line item into the <u>inventory</u>	IMC(\$/item)	IAC(\$/item) IPC(\$/item)	
input variables: IAC, IPC	IMC = IAC + IPC		
2. Recurring management cost to maintain a line item in the <u>wholesale inventory</u>	RMC (\$/item-yr)	RAC RPC(\$/item-yr)	
input variables: RAC, RPC	RMC = RAC + RPC		
3. Number of pages of base level technical <u>documentation</u>	JJ	J	

Table IV (Continued)

Input Data Items	LSC	ORLA	MOD-METRIC
F. Logistics Administration (cont.)			
input variable: J for each FLU	$JJ = \frac{\sum J}{NSYS}$		
<hr/>			
4. Same as item 3 for depot	H	H	
<hr/>			
input variable: H for each FLU	$H = \frac{\sum H}{NSYS}$		
<hr/>			
5. Average packing and shipping cost to CONUS locations	PSC (\$/lb)		
6. Packing and shipping labor rate - CONUS		PSLRCON(\$/lb)	
7. Packing and shipping material rate - CONUS		PSMRCON(\$/lb)	
8. Shipping rate - CONUS airlift		SRICON(\$/lb)	
9. Shipping rate - CONUS non-airlift		SRNCON(\$/lb)	
<hr/>			
input variables: PSLRCON, PSMRCON, SRICON, SRNCON	$PSC = PSLRCON + PSMRCON + \frac{SRICON + SRNCON}{2}$		
<hr/>			
10. Same as item 5 for OS	PSO(\$/lb)		
11. Same as items 6-9 for OS		PSLROS(\$/lb) PSMROS(\$/lb) SRIOS(\$/lb) SRNOS(\$/lb)	
<hr/>			
input variables: PSLROS, PSMROS, SRIOS, SRNOS	$PSO = PSLROS + PSMROS + \frac{SRIOS + SRNOS}{2}$		

The input routine uses the LSC model requirements as the beginning framework. This was done because LSC is a basic tool of logistics acquisition modelling --- encompassing both level of repair and spares provisioning decision indicators. In addition, LSC provides more timely turnaround and is, thus, more attractive in terms of input characteristics. Wherever possible, the variable names used by LSC have been retained.

The initial input routine consists of an interactive question and answer sequence in which the user inputs the applicable data. The routine computes the aggregate variables and then writes a data array onto a file predesignated by the user. Segments of the data array can then be accessed and attached to the applicable model. Appendix B describes the actual "hands-on" procedure.

Input Data Variables

Constructing the data file as described above requires a slightly different cut of the data than was presented in Tables II - IV. The input routine groups the data into five categories according to the sequence prescribed for the LSC model. Two more categories are added, one each for ORLA and MOD-METRIC peculiar variables. The resultant seven categories are:

1. Weapon system
2. Propulsion
3. System
4. FLU
5. Support Equipment
6. ORLA
7. MOD-METRIC

Table V
VARIABLE INPUT SEQUENCE

Weapon System

UR M OSTICON OSTNCON OSTIOS OSTNOS
PIUP UE OS IAC IPC RAC RPC
PSLRCON PSMRCON SRICON SRNCON PSLROS PSMROS SRIOS SRNOS
TRB TRD TD SA PMB PMD
PFFH EBO NSYS MRO MRF SR TR

Propulsion

EPA EUC CMRI ENRTS ERMH EOH FR
CONF ARBUT BP DP FC LS

System

XSYS SYSNOUN
BCA DCA BPA DPA FLA SMH TE N
YI ZI SMI BLR DLR

FLU

NFLU
XFLU FLUNOUN NHA
QPA UC NRTS BRCT DPL DSS
MTBF UF RIP BMC DMC W
BMH DMH SC PA PP K CS
IH FF FD H J YD ZD
PAMH IMH RMH BCMH SP
COND

Support Equipment

NSE
XSE
CAB CAD BUR DUR COB COD DOWN

ORLA

PWRCON PWROS
K1 K2 K4 SW X W AIR/NONAIR

MOD-METRIC

YMTBD PLT ALC

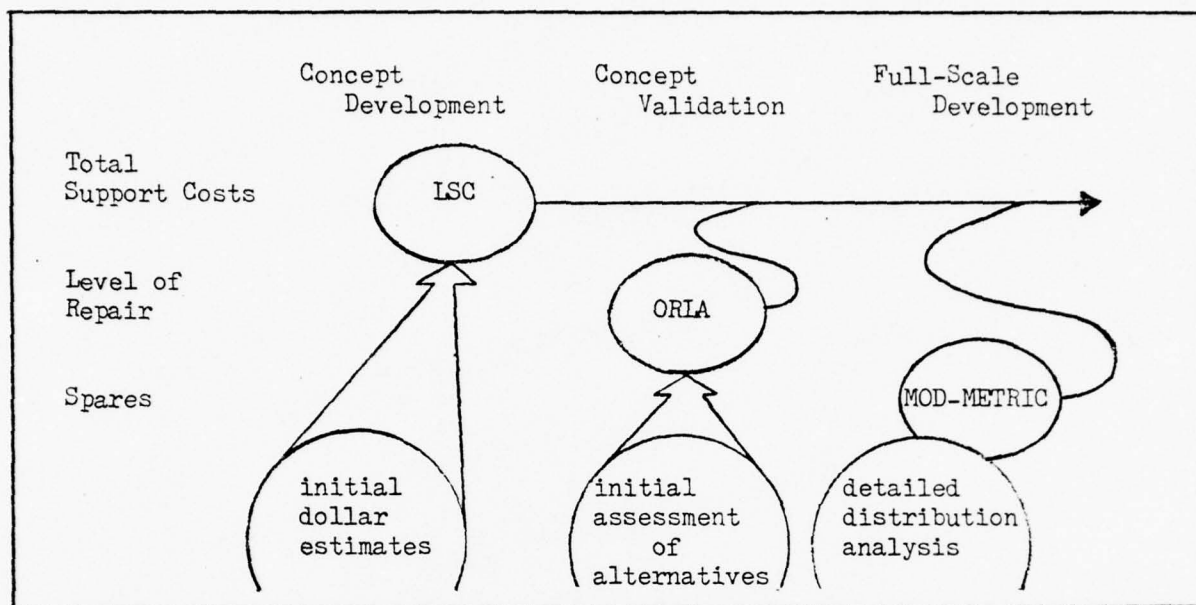


Fig. 4 Model Application Sequence

Table V shows the sequence in which variables are entered. The reader will note the addition of certain elements which have not appeared in the previous input lists. Such names as XSYS, SYSNOUN, XFLU, etc. are general housekeeping entries which will identify specific item designations and names in the program outputs. Appendix C of this study and the LSC user's manual describe these elements more fully.

Conclusion

Because the model user is not likely to have firm data early in the acquisition cycle, he would probably make a few rough cuts at analyzing the available data on specific aspects of the problem using the LSC model. Figure 4 shows "normal" progression of model usage during the first three stages of the acquisition cycle. Using

a model compatible input routine such as the one described in this chapter, the user can, by adding a few extra data items, utilize all three models to make planning estimates while the system is still in concept development.

The FORTRAN input routine described in this chapter is reproduced in Appendix A. As mentioned previously, the input routine deals only with establishing a compatible data base for the three models. For detailed description of the model computer codes and output products, References 12, 15 and 18 should be consulted. The purpose for developing a single input formulation is to consolidate the use of the models, thereby making them more accessible to the user. Appendix B at the end of this study should be helpful in this respect, because it describes the actual implementation of the models on the CREATE system using the input routine.

Chapter VII

Iterative Use of the Models

Until now this study has been directed toward explaining the use of logistics models in the acquisition process in general and consideration of the LSC, ORLA and MOD-METRIC models, in specific. The use of Logistics models, one at a time, to solve individual parts of the logistics support problem will probably remain the normal means of analysis for the acquisition manager. This occurs for two reasons. First, different aspects of the problem reveal themselves at different points in the development cycle. There is a continuing requirement for analysis and review of these differing areas, which realistically means that the logistics planner will be primarily interested in only certain information from certain models to solve current problems. Second, as mentioned in Chapter IV, a large model which attempts to do it all might become too tedious to use for only elemental portions of a problem. This defeats --- or at least limits --- the usefulness of models in general.

The interaction of models, as viewed in this study, is directed at using model outputs to improve, in some sense, the data that will be input to another model for analysis. The models retain their individuality, but the decision maker can transform selected output from one source into required input for a different model. The result is an interaction of the models chosen by the analyst to investigate the problem.

Because the decisionmaker is the key in putting the models to work on the problem, it is impractical to design a routine for computer use that mechanically picks and chooses among maxima or minima and tries to connect all the models automatically. The computer, however, can be used to facilitate this connection if it allows the user to evaluate parameters of interest from one set of output and then update the input files for the other model(s) being used.

This chapter looks at the degree of interaction that can be achieved among the LSC, ORLA and MOD-METRIC programs in the context that has just been described. First the varying types of output available from the computerized versions of the three models are described. Then the specific output elements that provide a connecting link among the models are isolated. Finally, a procedure and an illustrative example are presented through which the user can utilize the decision indicators output by individual models to affect a degree of interaction among all the models.

LSC, ORLA and MOD-METRIC Output Products

The output available from the LSC model in the time-shared mode contains the total logistics support cost for the system followed by up to nine different forms of information. The user can select from the following options:

1. The total weapon system LSC; broken out among the ten equations.
2. All systems ranked in decreasing order of total cost.
3. Total cost for a specified system; broken out among the ten equations.
4. For a specified system, component FLUs ranked by cost.

5. Total cost for a specified FLU; broken out among the first seven equations.

6. A detailed SE analysis. Each line item of SE in the system is listed along with the computed fractional quantities required (base and depot) and the integerized total requirements.

7. A spares analysis showing the stock level, pipeline, and condemnation replacement quantities required for whole engines and FLUs.

8. A maintenance generations analysis showing the peak and total FLU maintenance generations both on and off-equipment.

9. A FLU work unit code and noun description cross-reference (Ref 12:16-17).

The model may also be run in the batch mode, in which case all of the options are provided with each run.

The ORLA computer model is executed in the batch mode only.

The output product contains three summaries:

1. Constants for the run, which lists the standard input data elements.

2. An economic and sensitivity analysis, by item, along with the item variable input data. The economic analysis provides the cost figures for making the repair level decision.

3. A repair level summary, which contains only essential item information and the repair level decision determined by the economic analysis (Ref 15:4-6).

The ORLA computer package will also compute a support equipment summary. However, this option was not considered in this study because a similar capability exists with the LSC model.

The MOD-METRIC computer model is available in several versions. Only the MOD-METRIC/ONEIND version is considered in this study. It is a one indenture, two echelon model which is compatible with the LSC FLU or ORLA LRU-SRU concepts for a base (intermediate) and depot maintenance system. The output product includes marginal analysis of spares quantity and distribution, and the reduction in expected

backorders for end items that are achieved by increasing the level of spares investment.

Connecting Output Elements

Embodied in the output products just described are certain connecting elements which tie the models together. Each of the models addresses a different aspect of the logistics acquisition problem and, consequently, their outputs are tailored to different uses. For that same reason, certain output elements in the models can be used to supply information to the other models that would otherwise be unknown or, at most, uncertain. Using LSC as the basic model, consider the contributions that can be made by ORLA and MOD-METRIC to the LSC input base.

The ORLA model is concerned with estimating the costs of three alternatives for a FLU: repair at depot, repair at base or discard-at-failure. This decision translates directly into one of the most critical variables in the LSC model --- the determination of the NRTS rate. If the repair-level decision is to repair a certain FLU only at depot, the NRTS rate is 100% of 1.00. If a discard-at-failure decision is made, NRTS = 0 and COND, another critical LSC variable, is set equal to 1.00. The LSC model can then use these rates to credit the applicable depot or base cost accounts for such things as materiel or labor. (These rates are also used by the MOD-METRIC model.)

In the area of spares provisioning, the determination of EBO, the expected number of backorders for an LRU that exist at a base at any point in time, is a highly uncertain estimate unless a standard or policy figure can be determined. By design, EBO is one of the

outputs of the MOD-METRIC model. It can be determined by the MOD-METRIC model and then inserted into the LSC data base where it is used in the equation described in Chapter V to find the minimum value of STK, the number of spares required to fill the base repair pipeline plus a safety stock. A review of that equation shows that NRTS is also used. The result is that the dynamics of the model interactions are compounded without any reduction in the generality of the models.

As would probably be the case, the logistics planner might make an analysis of available data with the LSC model early in the acquisition cycle. Some of this output can be used in subsequent applications of the ORLA and MOD-METRIC models. ORLA requires estimates for the number of depot and base maintenance personnel required to be trained over the life of the system. LSC equation C_6 can be used to derive these estimates. The MOD-METRIC model uses the level of spares investment to perform its marginal analysis. LSC equation C_1 can provide an early estimate of cost for FLU spares. Although the quantity EBO required in equation C_1 will not have been optimally determined, the spares cost output should provide an approximation of the investment levels that should be considered.

Secondary Input Routine

Table VI shows some of the variables that provide a connecting link between models. These variables can be added to the input files described in the previous chapter by using the secondary input routine shown in Appendix A. The second routine simply overwrites the changed or updated variables in the proper locations in the original input files.

Table VI
CONNECTING VARIABLES

Input Data Item	Variable Name
1. Fraction of removed FLUs expected to be returned to depot for repair	NRTS
2. Fraction of removed FLUs expected to be condemned at base level	COND
3. Expected number of unfilled demands existing at a base at any point in time	EBO
4. Estimate of spares investment level	cost of FLU spares

The variables included in Table VI are the major elements which show the areas in which the models can be made to interact. Other outputs may also emerge which can be used to update the inputs to one of the other models. These can be entered by adding the appropriate lines to the secondary input routine.

Illustrative Example

A hypothetical weapon system containing two single-indentured FLUs can serve to illustrate the use of the models in an integrated framework. The analysis is built around LSC equation C_1 , the cost of FLU spares, which was detailed in Chapter V. The reader will recall that the equation's three terms concern costs to fill the base repair pipeline, the depot pipeline and to replace failed FLUs which will be condemned at base level over the life of the system. As noted in the previous sections, these costs are influenced by both the NRTS rate and EBO --- elements which can be evaluated by the ORLA and MOD-METRIC models, respectively.

The data elements which make up that part of the LSC data base used by equation C_1 are as follows:

	FLU1	FLU2
M - number of bases	2	2
UC - unit cost (\$)	14994	4728
FFFH - peak force flying hours (hrs/mo)	700	700
QPA - quantity per application	1	1
UF - ratio of operating/flying hours	1.1	1.1
RIP - repaired in place	.05	.05
NRTS - (to be determined by ORLA application)		
DRCT - depot repair cycle time (mo.)	1.5	2
TFFH - total force flying hours	84000	84000
TFFH = UR (PIUP)(12)		
= 700 (10)(12)		
COND - condemnation rate	.05	.01
BRCT - base repair cycle time (mo.)	.2	.2
OSTCON - shipping time - CONUS (mo.)	.4	.4
OS - percentage overseas	0	0
MTBF - mean time between failures (hrs)	2890	8436
EBO - initial system-wide standard of .10. (To be investigated for various budget levels by MOD-METRIC application.)		

A spares analysis of the two FLUs can use the models in the following sequence:

1. The repair-level for each of the FLUs is determined using the above data elements as part of an ORLA data base.
2. The LSC model is exercised to estimate the cost of spares (starting budget) for each FLU.
3. The MOD-METRIC model, based on the same data elements and the NRTS rates determined by ORLA, is used to investigate the optimal spares distribution which may serve to improve EBO for the two FLUs below the system standard.

The ORLA repair-level summary indicates the projected cost of maintaining a FLU in each of the three possible repair options. As noted in Chapter V, each cost estimate considers only the differential costs associated with a particular maintenance alternative. It is for this reason the ORLA model cannot be considered a true life cycle cost model. The measure of merit in selecting a maintenance posture with

the ORLA model is relative cost among the three alternatives. The following list shows the ORLA costs for FLU1 and FLU2. In addition, Option 5 of the LSC model was exercised to show the comparative FLU spares cost of adopting each maintenance policy. (Recall that when applied to the LSC model, base level repair equates to a NRTS rate of 0; depot repair to a NRTS = 1.0; and the discard option sets NRTS = 0 and COND equal to 1.0).

ORLA REPAIR-LEVEL	BASE	DEPOT	DISCARD-AT-FAILURE
FLU1	\$124230	\$ 97542	\$539834
FLU2	<u>43722</u>	<u>27300</u>	<u>56634</u>
Total	\$167952	\$124842	\$596468
LSC SPARES COST			
FLU1	\$112735	\$104958	\$545387
FLU2	<u>948</u>	<u>9456</u>	<u>58652</u>
Total	\$122683	\$114414	\$604039

Comparison of the above totals shows that both the relative ORLA repair-level costs and the LSC spares costs indicate a depot repair decision for the FLUs. The usefulness of the ORLA model as an aid to LSC is that it need be run only once to determine the repair-level for up to 100 FLUs; whereas the LSC model would require three runs with appropriate NRTS or COND updates in-between to make the same decision based on spares cost.

With a NRTS rate of 1.0 added to the LSC data base, Option 5 of the model was selected to display the cost for a stipulated FLU broken out among the first seven equations. Equation C_1 indicated a cost for FLU spares for FLU1 of \$104,958; for FLU2, \$9456. Option 7 provides a detailed spares analysis, breaking out

the integerized totals for the three terms of equation C_1 :

	TOTAL	STK (each base)	DEPOT PIPELINE	TOTAL COND
FLU1	7	2	1	2
FLU2	2	0	1	1

The condemnation totals are for the service life (PIUP = 10 yrs) of the system. FLUs are assumed to be reordered as condemnation occurs. Both the base stock and depot pipeline quantities are one-time buys to initially provision the respective repair pipelines. This spares analysis provides a frame of reference for the following discussion of the MOD-METRIC model.

Applying the MOD-METRIC model to the data results in a range of budgets. The initial budget is the pipeline cost (no base stock) computed by MOD-METRIC. Succeeding budgets are developed by increasing base stock (usually by one FLU per base) up to a maximum of 20 budgets. As would be expected, each budget increase causes a decrease in the corresponding EBO rate. The area of interest in this example is a budget level in the vicinity of \$114000 (the LSC spares cost for FLU1 plus FLU2). The MOD-METRIC model produced the following spares distribution in this area:

	TOTAL	BASE A B		DEPOT	COND
FLU1	7	2	2	2	1
FLU2	1	0	0	1	0
TOTAL COST	\$109686				
EBO	.0803				

The results of this analysis differ from the LSC computation in two areas. First, the number of items condemned is lower. This is explained by noting that MOD-METRIC computes a probabilistic

condemnation factor on a yearly basis, while LSC makes a deterministic estimate for the entire life cycle. Which method is more accurate depends on the perspective of the model user. More significant however, is that the allocation of one additional FLU1 to the depot pipeline reduces EBO below the system standard of .10. Using the optimal spares distribution of MOD-METRIC and the condemnation totals of LSC, the following spares requirements can be proposed:

	TOTAL	BASES	DEPOT	COND
FLU1	8	4	2	2
FLU2	2	0	1	1
TOTAL COST	\$129408			

The MOD-METRIC analysis shows that this will maintain an EBO of .0803. As a point of interest, changing the system standard for EBO to .08 in the LSC model increases the base stock requirement to 3 per base for FLU1. Other quantities remained the same, resulting in an LSC spares cost of \$159396. Therefore, the MOD-METRIC analysis shows that optimal distribution can reduce both the quantity and cost for spare FLUs over similar LSC analysis. It does, however, pose a problem for the decisionmaker: whether the decrease in EBO is worth the increased spares cost from the original LSC level of \$114414 to the proposed \$129408 caused by an additional FLU1. This judgement is beyond the scope of either MOD-METRIC or LSC.

Another way to use the MOD-METRIC model to investigate EBO for LSC application is to plot the change in EBO versus FLU spares cost as shown in Figure 5. This data is readily available from the range of budgets produced in a single MOD-METRIC run. This marginal technique can help the analyst to select an EBO rate for system-wide

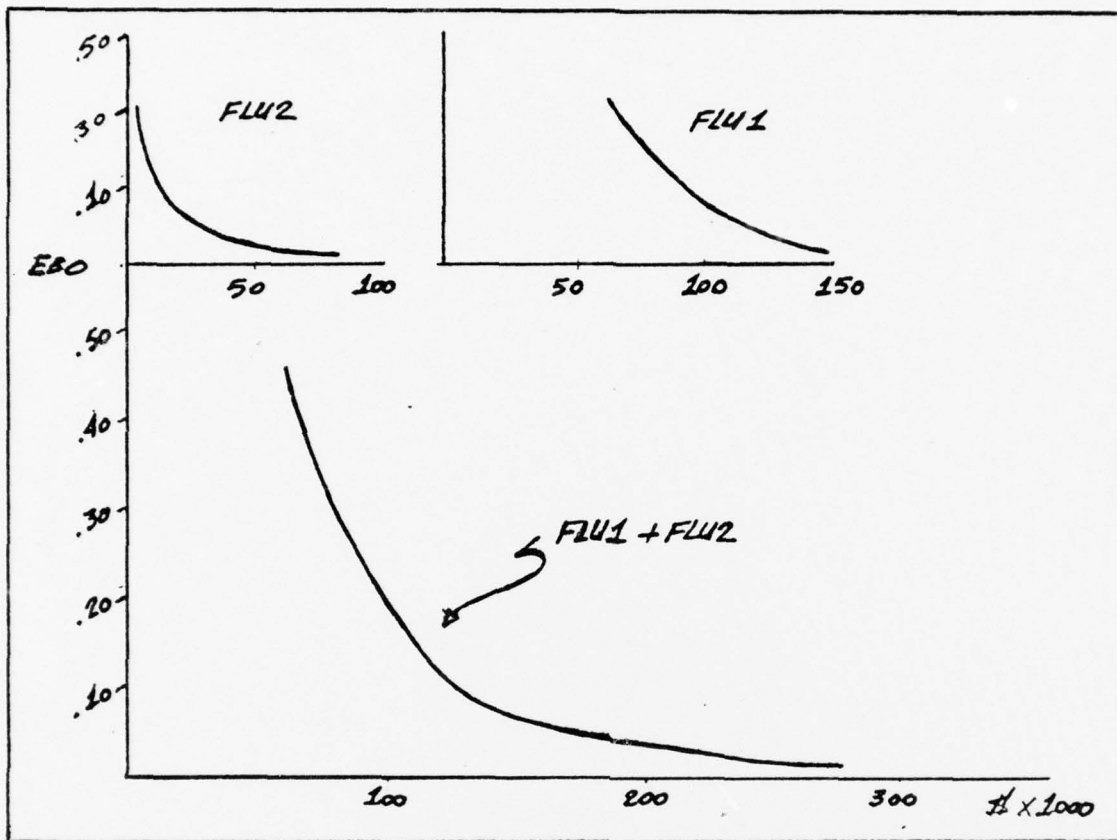


Fig. 5. Backorder - Cost Curve

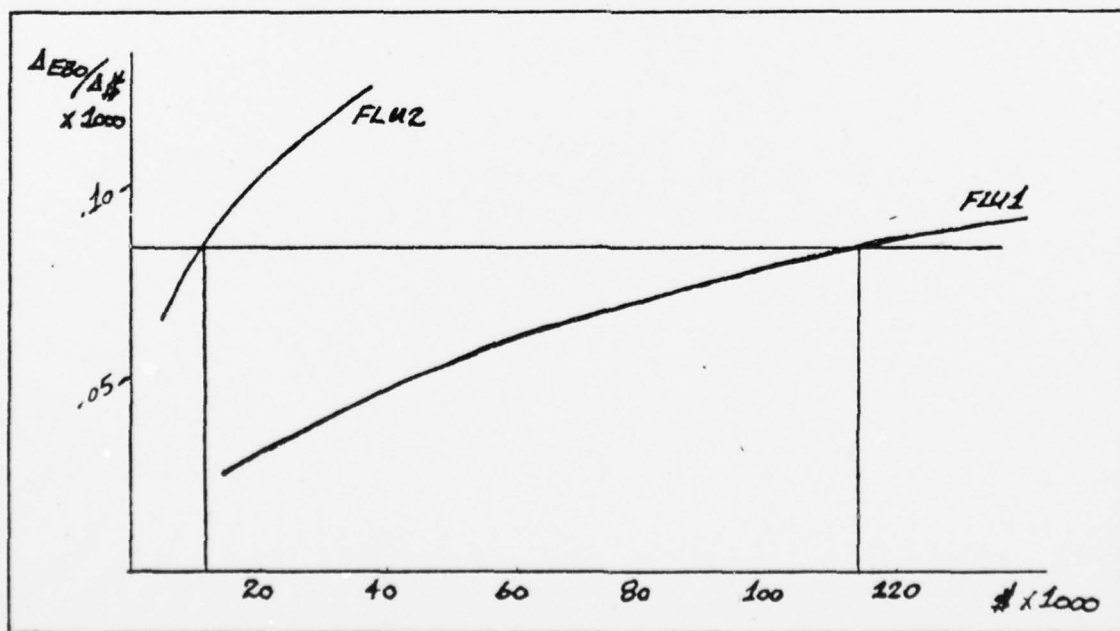


Fig. 6 FLU Cost Curve

application in the LSC model while, at the same time, graphically depicting the range of FLU spares costs that are a consequence of the EBO selection. To complete a similar analysis using the LSC model alone requires multiple runs of the model with some arbitrarily changing EBO rate to establish the graphical data points. A numerical representation of this procedure is available using the MOD-METRIC COMBINE program described in Ref. 18. No change to the MOD-METRIC data base is required.

An additional spares analysis can be made by plotting the change in EBO per budget dollar against FLU spares cost. This analysis is useful for projecting an optimal EBO rate for each FLU instead of a system-wide standard. The individual FLU cost curves shown in Figure 6 can be derived from the MOD-METRIC budget analyses used previously.

To solve for an optimum EBO, the analyst sets up a Lagrangian function to minimize EBO for FLU1 plus FLU2 subject to the constraint that total cost equal cost of FLU1 plus FLU2. Graphically, this is equivalent to selecting the point where $f_1'(C_1) = f_2'(C_2)$ as shown in Figure 6. The appropriate FLU spares costs can then be determined. Although requiring analysis outside the scope of the MOD-METRIC model, the results optimize individual FLU EBO rates and, as such, provide additional decision information to the LSC model user.

This example shows some of the possibilities of using the three models, in conjunction, to make repair level decisions, estimates of starting budgets and optimal allocations of spares to achieve an EBO rate below the system standard. The procedure does not remove the analyst from the decision process but it can facilitate his

capability to conduct detailed investigations into specific areas of the logistics support problem.

Conclusion

The degree of interaction that can be achieved with the three models derives from the special purpose in the acquisition process each was designed to serve. The repair-level decisions of ORLA and the spares policies calculated by MOD-METRIC are valuable inputs to the LSC model. It must be recognized, however, that the "quality" of weapon system data early in the acquisition cycle will probably predispose the logistics planner to use the LSC model first. It is for this reason that the initial input routine places the LSC input requirements first. The secondary input routine is designed to simplify the update of the LSC input file with ORLA and MOD-METRIC decision indicators as data is refined later in the cycle.

The role of the decisionmaker is the key to allowing the models to interact. Each of the models retains its individuality in terms of execution and output. The logistics planner can make use of the specialized output that each provides. The use of the input routines described in this study can facilitate his use of the output elements which connect the three models.

Chapter VIII

Conclusion

This study has had at its center two principal goals: to make the LSC, ORIA and MOD-METRIC models better understood among logistics planners, and to make the computer use of the models more accessible. The procedures and recommendations of the Battelle SCALE report described in Chapter IV were the basis for setting these goals. To assess the success or failure of this attempt, it is necessary to compare the outcome with the requirements of the SCALE proposal. The three areas of concern were: the description of the models, the development of a compatible set of input variables, and the description of areas of interaction, or "connecting links", among the models.

The model descriptions in Chapter V were aimed at making the methods and purpose of the models more apparent. While admittedly not exhaustive, Chapter V, and the background material in Chapters II and III, portray the overall concept of ILS and the specifics of analytic modelling in terms of three models. By collecting the characteristics of the models in one chapter, it is hoped that the understanding of the different purposes, yet common base, of the models will be enhanced.

The model compatible input routine developed in Chapter VI is of some importance to this study, not because it results in a computer routine for transforming input variables, but because it pinpoints areas where model-to-model inconsistencies can be alleviated.

It also shows the simplifying assumptions that have to be made to keep model integration manageable. This is particularly true in transforming the aggregate variables (Table IV). The overall result of Chapter VI is, ideally, to make the models more accessible and easier to use.

The iterative use of the models is perhaps the least conclusive area of this study. The SCALE proposal recommended the development of an iterative framework to "synergistically access the best features." This is tacit recognition that each model was designed to excel in a specific area of logistics support planning. The admonition against developing a single, large model combining all of the "best" features also comes into play. What surfaces is the realization that individual decision makers must extract those certain parameters from individual models which they determine are significant. For this reason, the model interaction described in Chapter VII is more of a scheme than a procedure. The secondary input routine included as part of the computer transformation routine is an attempt to illustrate how these "significant" variables can be included in an integrated framework. It is not a complete listing of the "connecting links" among the models and should not preclude the decision maker from incorporating other variables of interest.

Before and After

At the outset of Chapter VII, it was noted that the LSC, ORLA and MOD-METRIC models must maintain their individuality to be of use in the differing facets of logistics acquisition modelling. It was for this reason that no attempt was made to alter the individual model algorithms or output products. The only remaining area in which differences can occur in the use of the models is the formulation

of the input data base. The problem involved here is best resolved by reviewing the variable descriptions in Chapter VI. In particular, the relationships developed for the Aggregate Variables in Table IV are significant. The main obstacle in determining the variable candidates for inclusion in the transformation routine revolves around the level of data aggregation required by each of the models. As the reader will recall, only the LSC model considers data at a system level. In order to simultaneously satisfy this requirement, and provide the ORLA or MOD-METRIC models with similar data at FLU level, the approach was taken to enter data at the lowest echelon, usually FLU, then aggregate and average it to make it compatible with higher level requirements. The specific instances of this should be apparent from Table IV. The decision to use the models individually, or in the integrated framework proposed in this study, hinges on whether the reader can accept this method of aggregating the data.

The implication of using an integrated framework for the models, over and above the problems associated with data aggregation, centers on data availability at different points during the acquisition cycle. As a result of this study, it has become apparent to the researcher that an integrated framework is most useful during the early phases of acquisition management. Although the input data items are, at this point, rough estimates; the use of the models together can serve two important purposes:

1. They can give indications of the sensitivity and scope of initial planning factors and broad cost estimates.
2. They give the logistics planner an insight to the type and quantity of specific data that will be required as the cycle progresses.

As the acquisition process continues, it is usually necessary to alter the specific models to account for system peculiarities and to obtain more accurate cost estimates. At this juncture it might be more productive to build separate data bases and run the models individually. But, having used an integrated framework, the planner would have a basic data base and knowledge of how certain elements in one model relate to those in another.

Some Comments

This study has attempted to describe the potential value of integrating the LSC, ORLA and MOD-METRIC models. One of its shortcomings has been the necessity to abbreviate and generalize the descriptions of the models themselves. For this, the reader is directed to the model user's guides listed in the bibliography. In addition, the study will be of only theoretical interest until it has been applied to the development of a real Air Force weapon system and all the resulting pitfalls and possibilities analyzed. To do this, many alterations and refinements to the material presented here will undoubtedly be needed.

It is, however, hoped that a case has been sufficiently made which reinforces the SCALE proposal. That is, that the three models discussed in this study can be better understood and more accessible to the user. There exists a potential for integrating the models by way of a common data base. And that by using the best features of the models in an iterative fashion the logistics support costs of choosing a particular weapon system can be more accurately determined.

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Appendix A

A FORTRAN Input Routine

```

10  DIMENSION WS(15,8),FL(40,7),RL(11,6),TR(10,2),AG(12,13)
20  DIMENSION NSE(30),NAIR(10)
30  CHARACTER XSVS*5(4),XFLU*5(10),XSE*5(30),ALC*1(10)
40  CHARACTER SVSHOUN*20(4),FLUNOUN*16(10),XNHA*20(4)
50  CALL ATTACH(30,"GSA76D/TAI2;",3,0,,)
60  CALL ATTACH(40,"GSA76D/TAI3;",3,0,,)
70  CALL FMEDIA(30,5)
80  CALL FMEDIA(40,5)
90  100 FORMAT(A8)
100 101 FORMAT("//20X,"LSC INPUT FILE")
110 102 FORMAT(U)
120 103 FORMAT("//20X,"ORLA INPUT FILE")
130 104 FORMAT(8F9.2,A8)
140 105 FORMAT(8F9.2,6X,"C2")
150 106 FORMAT(8F9.2,6X,"C3")
160 107 FORMAT(8F9.2,6X,"C4")
170 108 FORMAT(4F9.2,42X,"C5")
180 109 FORMAT(I3,7X,2A10,3A10,2A10)
190 110 FORMAT(F8.0,4F5.2,2X,I1,45X,I3,"2")
200 111 FORMAT(8F9.2,4X,I3,"3")
210 112 FORMAT(8F9.2,4X,I3,"4")
220 113 FORMAT(7F9.2,13X,I3,"5")
230 114 FORMAT("//20X,"MOD-METRIC INPUT FILE")
240 115 FORMAT("11",1X,A8,A16,1X,"KK",A7,A6,A4,A3,I2,3F3.0,A1)
250 116 FORMAT("92",1X,"MOD-METRIC ONEIND INPUT")
260 117 FORMAT("91",1X,"NBIS BETA BSTART BSTOP CFAC")
270 118 FORMAT("91",1X,"WUC",5X,"PART NUMBER",9X,"COST",2X,
280  "MTBD",1X,"NRTS",1X,"C",1X,"Q",1X,"BRT",1X,"D",1X,"PLT")
290 119 FORMAT("97",1X,I3,F6.0,F3.0,F6.0,F3.0,F6.0,F3.0,
300  F6.0,F3.0,F6.0,F3.0,F6.0,F3.0)
310 120 FORMAT("99",1X,"010",2X,"3.00",F6.2,2X,"0.01",F6.2)
320 121 FORMAT("98",1X,"06000000")
330 122 FORMAT(F9.0,F7.0,5F7.2)
340 123 FORMAT(8F7.2)
350 124 FORMAT(6F7.2,2F7.0)
360 125 FORMAT(F3.0,F9.0,5F8.2)
370 126 FORMAT(6F7.2)
380 127 FORMAT(F8.0,3F9.0,3F8.0,F5.0)
390 128 FORMAT(2F9.0,2F6.0,2F5.0,2F7.0,F9.0)
400 129 FORMAT(4F7.2,2F6.0)
410 130 FORMAT(F4.0,F8.0,F6.0,7F6.2)
420 131 FORMAT(4F6.2,F7.2,6F6.0)
430 132 FORMAT(2F6.2)
440 133 FORMAT(2A10,2F9.0,5F5.2)
450  Y=1.0
460  N=0

```

```

470 PRINT: "DURING QUESTION SEQUENCE, TYPE 1.0 FOR YES, 0 FOR NO"
480 PRINT: "INITIAL INPUT ROUTINE? (Y OR N)"
490 READ: ANS1
500 IF(ANS1.EQ.N) GO TO 1
510 PRINT: "INITIAL INPUT ROUTINE"
520 PRINT: "WEAPON SYSTEM VARIABLES"
530 PRINT: "ENTER UR, N, OSTICON, OSTNCON, OSTIOS, OSTNOS"
540 READ: ((WS(K,L),L=1,6),K=1,1)
550 PRINT: "ENTER PIUP, UE, OS, IAC, IPC, RAC, RPC"
560 READ: ((WS(K,L),L=1,7),K=2,2)
570 PRINT: "ENTER PSLRCON, PSMRCON, SRICON, SRNCON, PSLROS,
580 PSMROS, SRIOS, SRNOS"
590 READ: ((WS(K,L),L=1,8),K=3,3)
600 PRINT: "ENTER TRB, TRD, TD, SA, PMB, PMD"
610 READ: ((WS(K,L),L=1,6),K=4,4)
620 PRINT: "ENTER PFFH, EBO, NSYS, MRO, MRF, SR, TR"
630 READ: ((WS(K,L),L=1,7),K=5,5)
640 PRINT: "PROPULSION PECULIAR VARIABLES? (Y OR N)"
650 READ: ANS2
660 IF(ANS2.EQ.N) GO TO 2
670 PRINT: "ENTER EPA, EUC, CMPI, ENRTS, ERMH, EOH, FR"
680 READ: ((WS(K,L),L=1,7),K=6,6)
690 PRINT: "ENTER CONF, ARBUT, BP, DP, FC, LS"
700 READ: ((WS(K,L),L=1,6),K=7,7)
710 2 PRINT: "SYSTEM VARIABLES"
720 NSYS=WS(5,3)
730 M1=8
740 DO 3 IS=1,NSYS
750 PRINT: "ENTER XSYS, SYSNOUN"
760 READ: XSYS(IS), SYSNOUN(IS)
770 PRINT: "ENTER BCR, DCR, BPA, DPA, FLA, SMH, TE, N"
780 READ: ((WS(K,L),L=1,8),K=M1,M1)
790 PRINT: "ENTER YI, ZI, SMI, BLR, DLR"
800 READ: ((WS(K,L),L=1,5),K=M1+1,M1+1)
810 3 M1=M1+2
820 PRINT: "FLU VARIABLES"
830 PRINT: "HOW MANY FLUS IN WEAPON SYSTEM?"
840 READ: NFLU
850 M2=1
860 M3=1
870 DO 4 J=1,NFLU
880 PRINT: "ENTER XFLU, FLUNOUN, NHA"
890 READ: XFLU(J),FLUNOUN(J),XNHA(J)
900 PRINT: "ENTER QPA, UC, NRTS, BRCT, DPL, DSS"
910 READ: ((FL(K,L),L=1,6),K=M2,M2)
920 PRINT: "ENTER MTBF, UF, RIP, BMC, DMC, W"
930 READ: ((FL(K,L),L=1,6),K=M2+1,M2+1)
940 PRINT: "ENTER BMH, DMH, SC, PA, PP, K, CS"
950 READ: ((FL(K,L),L=1,7),K=M2+2,M2+2)
960 PRINT: "ENTER IH, FF, FD, H, JJ, YD, ZD"
970 READ: ((FL(K,L),L=1,7),K=M2+3,M2+3)
980 PRINT: "ENTER PAMH, IMH, RMH, BCHH, SP"
990 READ: ((FL(K,L),L=1,5),K=M2+4,M2+4)
1000 PRINT: "ENTER COND"
1010 READ: ((FL(K,L),L=1,1),K=M2+5,M2+5)

```

```

1020 PRINT: "HOW MANY PIECES OF SE FOR THIS FLU?"
1030 READ: NSE(J)
1040 M2=M2+6
1050 DO 5 JSE=1,NSE(J)
1060 PRINT: "SE VARIABLES"
1070 PRINT: "ENTER XSE"
1080 READ: XSE(M8)
1090 PRINT: "ENTER CAB, CAD, BUR, DUR, COB, COD, DOWN"
1100 READ: ((FL(K,L),L=1,7),K=M2,M2)
1110 M8=M8+1
1120 5 M2=M2+1
1130 4 CONTINUE
1140 PRINT: "ORLA PECULIAR VARIABLES? (Y OR N)"
1150 READ: ANS3
1160 IF(ANS3.EQ.N) GO TO 6
1170 PRINT: "ENTER PWRCOM, PWROS"
1180 READ: ((RL(K,L),L=1,2),K=1,1)
1190 M3=2
1200 PRINT: "ENTER K1, K2, K4, SW, X, W, AIR/NOHAIR FOR REQ'D FLUS"
1210 DO 7 JFL=1,NFLU
1220 PRINT: XFLU(JFL),FLUNOUNX(JFL)
1230 READ: ((RL(K,L),L=1,6),K=M3,M3),NAIR(JFL)
1240 7 M3=M3+1
1250 6 PRINT: "MOD-METRIC PECULIAR VARIABLES? (Y OR N)"
1260 READ: ANS4
1270 IF(ANS4.EQ.N) GO TO 8
1280 PRINT: "ENTER YMTBD, PLT, ALC FOR REQUIRED FLUS"
1290 M4=1
1300 DO 9 JFM=1,NFLU
1310 PRINT: XFLU(JFM),FLUNOUNX(JFM)
1320 READ: ((TR(K,L),L=1,2),K=M4,M4),ALC(JFM)
1330 9 M4=M4+1
1340C --- AGGREGATION ROUTINE ---
1350 8 PRINT: "PLEASE WAIT - AGGREGATE VARIABLES BEING COMPUTED"
1360 AG(1,1)=1.-WS(2,3)
1370 AG(1,2)=WS(1,1)*WS(2,1)*12.
1380 AG(1,3)=WS(1,1)/WS(1,2)
1390 AG(1,4)=WS(4,5)/11.
1400 AG(1,5)=WS(4,5)/48.
1410 AG(1,6)=WS(4,6)/11.
1420 AG(1,7)=WS(4,6)/48.
1430 AG(2,1)=(WS(1,3)+WS(1,4))*0.5
1440 AG(2,2)=(WS(1,5)+WS(1,6))*0.5
1450 AG(2,3)=(AG(2,1)+AG(2,2))*15.
1460 AG(2,4)=WS(2,4)+WS(2,5)
1470 AG(2,5)=WS(2,6)+WS(2,7)
1480 AG(2,6)=WS(3,1)+WS(3,2)+((WS(3,3)+WS(3,4))*0.5)
1490 AG(2,7)=WS(3,5)+WS(3,6)+((WS(3,7)+WS(3,8))*0.5)
1500 AG(1,10)=AG(1,2)/WS(5,1)
1510 M5=1
1520 M6=1
1530 M7=6
1540 DO 10 J1=1,NFLU
1550 AG(M5+2,1)=1.-FL(M6,3)
1560 AG(M5+2,2)=(FL(M6+2,1)+FL(M6+2,2))*0.5

```

```

1570 AG(M5+2,3)=(FL(M6+1,4)+FL(M6+1,5))*0.5
1580 AG(M5+2,4)=FL(M6,4)*30.
1590 AG(M5+2,5)=FL(M6,5)+FL(M6,6)
1600 AG(M5+2,6)=AG(M5+2,5)*30.
1610 AG(M5+2,7)=FL(M6+2,7)+FL(M6+3,1)
1620 DO 11 J2=1,NSE(J1)
1630 AG(M5+2,8)=AG(M5+2,8)+FL(M7,2)
1640 AG(M5+2,9)=AG(M5+2,9)+FL(M7,1)
1650 AG(M5+2,10)=AG(M5+2,10)+FL(M7,5)
1660 AG(M5+2,11)=AG(M5+2,11)+FL(M7,6)
1670 11 M7=M7+1
1680 AG(3,12)=AG(3,12)+FL(M6,4)
1690 AG(1,8)=AG(1,8)+FL(M6,5)
1700 AG(1,9)=AG(1,9)+FL(M6,6)
1710 AG(2,8)=AG(2,8)+(FL(M6+2,3)/FL(M6+2,1))
1720 AG(2,9)=AG(2,9)+(FL(M6+2,3)/FL(M6+2,2))
1730 AG(5,13)=AG(5,13)+FL(M6+3,7)
1740 AG(4,13)=AG(4,13)+FL(M6+3,6)
1750 AG(1,11)=AG(1,11)+FL(M6+2,7)
1760 AG(1,12)=AG(1,12)+FL(M6+3,1)
1770 AG(1,13)=AG(1,13)+FL(M6+3,4)
1780 AG(5,12)=AG(5,12)+FL(M6+3,5)
1790 AG(2,11)=AG(2,11)+FL(M6+3,2)
1800 AG(2,12)=AG(2,12)+FL(M6+3,3)
1810 M5=M5+1
1820 M6=M6+NSE(J1)+6
1830 10 M7=M7+NSE(J1)+6
1840 AG(3,12)=AG(3,12)/NFLU
1850 AG(1,8)=AG(1,8)/NFLU
1860 AG(1,9)=AG(1,9)/NFLU
1870 AG(2,8)=AG(2,8)/NSYS
1880 AG(2,9)=AG(2,9)/NSYS
1890 AG(5,13)=AG(5,13)/NFLU
1900 AG(4,13)=AG(4,13)/NFLU
1910 AG(1,11)=AG(1,11)/NSYS
1920 AG(1,12)=AG(1,12)/NSYS
1930 AG(5,12)=AG(5,12)/NSYS
1940 AG(1,13)=AG(1,13)/NSYS
1950 AG(2,11)=AG(2,11)/(MS(1,2)*NSYS)
1960 AG(2,12)=AG(2,12)/NSYS
1970 M5=1
1980 M6=1
1990 DO 12 J2=1, NSYS
2000 AG(M5+5,12)=AG(5,13)*WS(M6+8,2)
2010 AG(M5+5,13)=AG(4,13)*WS(M6+8,1)
2020 AG(2,10)=AG(2,10)+WS(M6+8,4)
2030 AG(4,12)=AG(4,12)+WS(M6+8,5)
2040 AG(2,13)=AG(2,13)+WS(M6+8,1)
2050 AG(3,13)=AG(3,13)+WS(M6+8,2)
2060 M5=M5+1
2070 12 M6=M6+2
2080 AG(2,10)=AG(2,10)/NSYS
2090 AG(4,12)=AG(4,12)/NSYS
2100 AG(2,13)=AG(2,13)/NSYS
2110 AG(3,13)=AG(3,13)/NSYS
2120 BSTART=1.0
2130 NBASES=WS(1,2)
2140 PRINT: "INITIAL INPUT ROUTINE COMPLETED"

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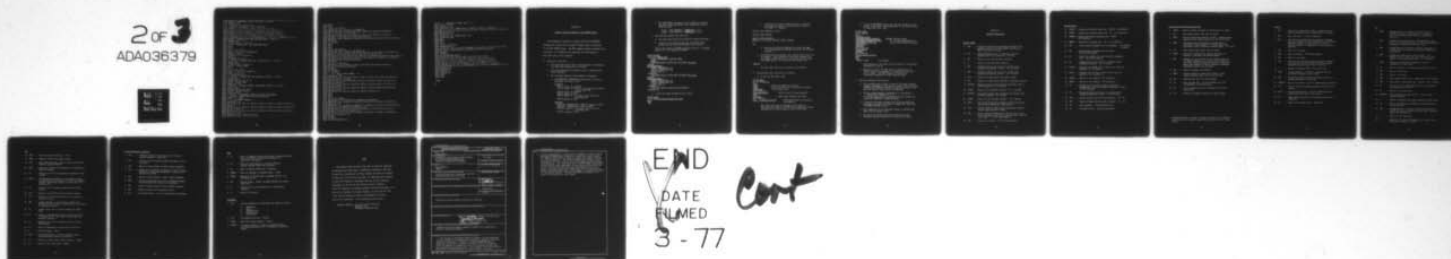
AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCH--ETC F/G 5/1
INTEGRATING OPTIMUM REPAIR-LEVEL ANALYSIS AND INVENTORY DECISIO--ETC(U)
DEC 76 P E TAIBL

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2150 PRINT: "SECONDARY INPUT ROUTINE? (Y OR N)"
2160 READ: ANS5
2170 IF(ANS5.EQ.N) GO TO 13
2180 1 PRINT: "SECONDARY INPUT ROUTINE"
2190 READ(40,102) NFLU,((NS(K,L),L=1,8),K=1,15),
2200((FL(K,L),L=1,7),K=1,40),((RL(K,L),L=1,6),K=1,11),
2210((TR(K,L),L=1,2),K=1,10),((AG(K,L),L=1,13),K=1,12),
2220((NSE(K),K=1,30),((NATR(K),K=1,10),((XSYS*5(K),K=1,4),
2230((XFLU*5(K),K=1,10),((XSE*5(K),K=1,30),((ALC*1(K),K=1,10),
2240((SYSHOUN*20(K),K=1,4),((FLUNOUN*16(K),K=1,10),((XNHA*20(K),K=1,4)
2250 PRINT: "CHANGE NRTS FOR SYSTEM FLUS? (Y OR N)"
2260 READ: ANS6
2270 IF(ANS6.EQ.N) GO TO 14
2280 PRINT: "ENTER NRTS FOR REQUIRED FLUS"
2290 M5=1
2300 M6=1
2310 DO 15 J3=1,NFLU
2320 PRINT: XFLU(J3),FLUNOUN(J3)
2330 READ: FL(M6,3)
2340 AG(M5+2,1)=1.-FL(M6,3)
2350 M5=M5+1
2360 15 M6=M6+NSE(J3)+6
2370 14 PRINT: "CHANGE COND FOR SYSTEM FLUS? (Y OR N)"
2380 READ: ANS7
2390 IF(ANS7.EQ.N) GO TO 16
2400 PRINT: "ENTER COND"
2410 M6=1
2420 DO 17 J4=1,NFLU
2430 PRINT: XFLU(J4),FLUNOUN(J4)
2440 READ: FL(M6+5,1)
2450 17 M6=M6+NSE(J4)+6
2460 16 PRINT: "CHANGE EBO FOR WEAPON SYSTEM? (Y OR N)"
2470 READ: ANS8
2480 IF(ANS8.EQ.N) GO TO 18
2490 PRINT: "ENTER EBO"
2500 READ: WS(5,2)
2510 18 PRINT: "CHANGE SPARES INVESTMENT LEVEL? (Y OR N)"
2520 READ: ANS9
2530 IF(ANS9.EQ.N) GO TO 19
2540 PRINT: "ENTER BSTART"
2550 READ: BSTART
2560 19 PRINT: "SECONDARY INPUT ROUTINE COMPLETED"
2570 13 PRINT: "ENTER DATE OF RUN: DD/MM/YY"
2580 READ: 100, DATE
2590C --- LSC INPUT ARRAY ---
2600 WRITE(30,101)
2610 WRITE(30,122) AG(1,2),WS(5,1),WS(12,1),WS(1,2),WS(2,3),WS(5,2),
2620WS(5,3)
2630 WRITE(30,123) AG(2,1),AG(2,2),AG(2,4),AG(2,5),AG(2,6),AG(2,7),
2640AG(4,1),AG(4,2)
2650 WRITE(30,124) WS(4,3),WS(4,4),WS(5,4),WS(5,5),WS(5,6),WS(5,7),
2660WS(4,5),WS(4,6)
2670 WRITE(30,125) (WS(6,L),L=1,7)
2680 WRITE(30,126) (WS(7,L),L=1,6)

```

```

2690 M5=8
2700 M6=6
2710 DO 20 J5=1,NSYS
2720 WRITE(30,102) XSYS(J5),SYSNOUN(J5)
2730 WRITE(30,127) WS(M5,1),WS(M5,2),WS(M5,3),WS(M5,4),WS(M5,5),
2740&AG(1,11),AG(1,12),WS(M5,8)
2750 WRITE(30,128) AG(2,11),AG(2,12),AG(1,13),AG(5,12),WS(M5,6),
2760&WS(M5+1,3),AG(M6,12),AG(M6,13),WS(M5,7)
2770 WRITE(30,129) AG(M5+1,4),AG(M5+1,5),AG(2,8),AG(2,9),AG(1,4),AG(1,6)
2780 M5=M5+2
2790 20 M6=M6+1
2800 M5=1
2810 M6=3
2820 M8=1
2830 DO 21 J6=1,NFLU
2840 WRITE(30,102) XFLU(J6),FLUNOUN(J6)
2850 WRITE(30,130) FL(M5,1),FL(M5,2),FL(M5+1,1),FL(M5+1,2),FL(M5+1,3),
2860&AG(M6,1),FL(M5,3),FL(M5+5,1),FL(M5+1,4),FL(M5+1,5)
2870 WRITE(30,131) FL(M5+4,1),FL(M5+4,2),FL(M5+4,3),FL(M5+4,4),FL(M5+2,1),
2880&FL(M5+2,2),FL(M5+1,6),FL(M5+2,4),FL(M5+2,5),FL(M5+4,5),FL(M5+2,6)
2890 WRITE(30,132) FL(M5,4),AG(M6,5)
2900 M5=M5+6
2910 DO 22 J7=1,NSE(J6)
2920 WRITE(30,133) XSE(M8),FL(M5,1),FL(M5,2),FL(M5,5),FL(M5,6),
2930&FL(M5,3),FL(M5,4),FL(M5,7)
2940 M8=M8+1
2950 22 M5=M5+1
2960 21 M6=M6+1
2970C --- ORLA INPUT ARRAY ---
2980 WRITE(30,103)
2990 WRITE(30,104) AG(3,12),AG(1,1),AG(1,7),AG(4,12),AG(1,8),AG(1,9),
3000&AG(1,5),AG(2,10),DATE
3010 WRITE(30,105) WS(2,4),WS(2,5),WS(1,2),WS(1,3),WS(1,5),WS(1,4),
3020&WS(1,6),WS(2,1)
3030 WRITE(30,106) WS(3,1),WS(3,5),WS(3,2),WS(3,6),RL(1,1),RL(1,2),
3040&WS(2,6),WS(2,7)
3050 WRITE(30,107) WS(4,4),WS(3,3),WS(3,7),WS(3,4),WS(3,8),WS(4,3),
3060&WS(2,2),WS(1,1)
3070 WRITE(30,108) WS(4,2),WS(4,1),AG(2,13),AG(3,13)
3080 M5=1
3090 M6=3
3100 M7=2
3110 DO 23 J8=1,NFLU
3120 WRITE(30,109) J8,XFLU(J8),FLUNOUN(J8),XNHAI(J8)
3130 WRITE(30,110) FL(M5+1,1),RL(M7,1),RL(M7,2),FL(M5+1,3),RL(M7,3),
3140&NAIR(J8),J8
3150 WRITE(30,111) FL(M5+3,3),AG(M6,11),AG(M6,10),FL(M5+3,2),FL(M5+3,4),
3160&FL(M5+3,5),FL(M5+2,4),FL(M5+2,5),J8
3170 WRITE(30,112) AG(M6,3),FL(M5,1),AG(M6,2),FL(M5+2,3),RL(M7,4),
3180&FL(M5,2),FL(M5+1,6),RL(M7,6),J8
3190 WRITE(30,113) RL(M7,5),FL(M5+3,6),FL(M5+3,7),AG(M6,7),AG(M6,8),
3200&AG(M6,7),AG(M6,9),J8
3210 M6=M6+1
3220 M7=M7+1
3230 23 M5=M5+NSE(J8)+6

```

```

3240C --- MODMETRIC INPUT FILE ---
3250 WRITE(30,114)
3260 WRITE(30,116)
3270 WRITE(30,119) NBASES,AG(1,3),AG(2,3),AG(1,3),AG(2,3),
3280&AG(1,3),AG(2,3),AG(1,3),AG(2,3),AG(1,3),AG(2,3),AG(1,3),AG(2,3)
3290 WRITE(30,121)
3300 WRITE(30,117)
3310 WRITE(30,120) BSTART,AG(1,10)
3320 WRITE(30,118)
3330 M5=1
3340 M7=1
3350 M6=3
3360 DO 24 J9=1,NFLU
3370 NQPA=FL(M5,1)
3380 WRITE(30,115) XFLU(J9),FLUNOUN(J9),FL(M5,2),TR(M7,1),FL(M5,3),
3390&FL(M5+5,1),NQPA,AG(M6,4),AG(M6,6),TR(M7,2),ALC(J9)
3400 M6=M6+1
3410 M7=M7+1
3420 24 M5=M5+NSE(J9)+6
3430 WRITE(40,102) NFLU,((WS(K,L),K=1,8),L=1,15),
3440&((FL(K,L),L=1,7),K=1,40),((RL(K,L),L=1,6),K=1,11),
3450&((TR(K,L),L=1,2),K=1,10),((AG(K,L),L=1,13),K=1,12),
3460&(NSE(K),K=1,30),NAIR(K),K=1,10),XSVS*5(K),K=1,4),
3470&(XFLU*5(K),K=1,10),XSE*5(K),K=1,30),ALC*1(K),K=1,10),
3480&(SYSNOUN*20(K),K=1,4),FLUNOUN*16(K),K=1,10),XNHA*20(K),K=1,4)
3490 ENDFILE 30
3500 ENDFILE 40
3510 REWIND 30
3520 REWIND 40
3530 STOP
3540 END

```

ready

*

Appendix B

Guide to Using the Models on the CREATE System

The information required to execute the LSC and MOD-METRIC programs can be input via any remote terminal which is connected to the AFLC CREATE system. The ORLA program currently requires card type input. An alternative for executing the ORLA program is described later in this Appendix.

A. Building an Input File

1. The user should review Table V and Appendix C to determine the input data required for the models.
2. The source program from Appendix A must be entered under user's filename.
3. The following changes to the program are necessary:
 - a. the DIMENSION & CHARACTER variables must be sized to accomodate the user's input:

DIMENSION

WS(X,8) where, $X = 7 + 2(NSYS)$
FL(X,7) where, $X = 6(NFLU) + 1$ for each item of SE for
an individual FLU
RL(X,6) where, $X = 1 + (NFLU)$
TR(X,2) where, $X = NFLU$
NSE(X) where, $X = 1$ for each item of SE for an
individual FLU
NAIR(X) where, $X = NFLU$

CHARACTER

XSYS*5(X), SYSNOUN*20(X), XNHA*20(X) where, $X = NSYS$
XFLU*5(X), FLUNOUN*16(X), where $X = NFLU$
XSE*5(X), where $X = 1$ for each item of SE for an
individual FLU
ALC*1(X), where $X = NFLU$

- b. The CALL ATTACH statements must be changed to indicate the proper input and output files (underlined portions typed by user):

```
input:  CALL ATTACH(40, "USERID/fn1;",3,0,,)
output: CALL ATTACH(30, "USERID/fn2;",3,0,,)
```

4. The user must reserve file space for:

- a. the output file which will contain the model data array.
- b. a file to save the data input via the initial input routine for use with the secondary input routine.

This is done using the ACCESS system as shown (cr - carriage return; fn - user supplied filename):

SYSTEM ?ACCESS

FUNCTION? CREATE FILE

CATALOG STRUCTURE TO WORKING LEVEL?

USERID

FILE NAME,SIZE(IN LLINKS),MAX SIZE,MODE? fn1,1,100

PASSWORD

~~NEDESKDESKDESKDESK~~ cr

GENERAL PERMISSIONS? R,W

SPECIFIC PERMISSIONS? cr

ACCESS FILE? cr

SUCCESSFUL.

FILE NAME,SIZE(IN LLINKS),MAX SIZE,MODE? fn2,1,100

PASSWORD

~~HDKDESKDESKDESKDESK~~ cr

GENERAL PERMISSIONS? R,W

SPECIFIC PERMISSIONS? cr

ACCESS FILE? cr

SUCCESSFUL.

FILE NAME,SIZE(IN LLINKS),MAX SIZE,MODE? cr

FUNCTION? cr

5. To run the source program the user types:

SYSTEM ?FORT

OLD OR NEW-OLD source program file name

READY

*RUN

- a. a question and answer sequence follows in which the user inputs the data in the order shown in Table V of Chapter VI. Example:

INITIAL INPUT ROUTINE? (Y OR N)

=

INITIAL INPUT ROUTINE

WEAPON SYSTEM VARIABLES

ENTER UR, M, OSTICON, OSTNCON, OSTIOS, OSTNOS

=

etc.

- b. data must be entered separated by a space or comma. It is recommended that decimal points be used whenever possible.

6. The question/answer sequence will continue until input file is complete. Upon completion of the input sequence the data array is written onto the file space reserved under the ACCESS system. To review the input array, type:

*OLD fn2

The data array will then be listed at the terminal.

B. Concatenating Files and Running the Models.

1. To run the LSC model, type:

SYSTEM ?FORT

OLD OR NEW-OLD fn2

READY

*RESEX (adds line numbers to the file)

*LIST (review data and note inclusive line numbers

of LSC input file)

*RESAVE fn2

*DATA SAVED fn2

*OLD AQM/TSSMOD,R

(call up the LSC source program)

READY

*SAVE fn3

(save under separate file name)

DATA SAVED fn3

*RUN fn3#fn2(ln-ln)"10" (concatenate files; ln-inclusive line numbers)

LSC output will then be displayed at the terminal. The user should refer to the LSC user's manual for further explanation of output available from the LSC model.

2. To run the MOD-METRIC model, the user must create a set of control cards because the program runs on the CARDIN system. To create this file, type:

```

SYSTEM ?CARD
OLD OR NEW-NEW
READY
*10#STRIP : ,8,16
*20$:IDENT:NNNNNN,USERID,YY      (NNNNNN- Problem number;
*40$:SELECTA:MODMETRIC/ONEIND    YY- two letter designation of
*50$:LIMITS:11.30K.,10K         output (line printer) facility)
*60$:DATA:05
*SAVE fn4
DATA SAVED -fn4
*9999$:ENDJOB
*SAVEfn5
DATA SAVED-fn5
*OLD fn4:fn2(ln-ln):fn5
READY
*RUN
  SNUMB # B380T                  (Job number)

```

After execution, the output will be printed at the facility designated in line 20.

3. Until such time as the ORLA model is available on the CARDIN system it is necessary to transfer the ORLA input file to cards. AFLC/MMO should be contacted for instructions regarding the ORLA computer model.

C. Using the Secondary Input Routine

1. The secondary input routine is part of the source program listed in Appendix A. The user will recall that the initial DIMENSION and CHARACTER variable inputs were stored in fn1 when the initial input routine was executed.
2. RUN the source program, responding NO to the request:
INITIAL INPUT ROUTINE? (Y or N)
The program will cycle to the secondary input routine and reload the DIMENSION & CHARACTER arrays.
3. A question and answer sequence will follow in which the user will be asked if he wishes to change NRTS, COND, EBO or SPARES investment level.
4. Upon completion of the secondary routine, a revised data array will be stored in fn2.
5. The use of the revised data array follows the same procedure described starting in instruction B, above.

Appendix C

Variable Definitions

WEAPON SYSTEM

1. EBO - Standard established for expected backorders (the expected number of unfilled demands existing at a base at any point in time).
2. IAC - Supply management cost to introduce a new FSN assembly into the AF inventory. (\$/item)
3. IPC - Same as 2 for a new FSN part. (\$/item)
4. M - Number of operating base locations.
5. MRF - Average man-hours per failure to complete off-equipment maintenance records. (S= .24 hours)
6. MRO - Average man-hours per failure to complete on-equipment maintenance records. (S= .08 hours)
7. NSYS - Number of systems within the weapon system.
8. OS - Fraction of total force deployed to overseas locations.
9. OSTICON - Order and shipping time (airlift investment item) to CONUS location. (S= .37 months)
10. OSTIOS - Same as 9 for overseas location. (S= .53 months)
11. OSTNCON - Order and shipping time (nonairlift investment item) to CONUS location. (S= 1 month)
12. OSTNOS - Same as 11 for overseas location. (S= 2 months)
13. PFFH - Peak Force Flying Hours (expected fleet flying hours for one month during peak usage period).
14. PIUP - Program Inventory Usage Period (operational service life of weapon system in years).
15. PMB - Direct productive manhours per man per year at base level (includes "touch time", transportation time, and setup time.) (S= 1500 hours/man/yr)
16. PMD - Same as 15 at depot. (S= 1500 hours/man/yr)

Weapon System

- 17. PSLRCON - Packing and shipping labor rate - CONUS. (S=\$.1868/lb.)
- 18. PSLROS - Packing and shipping labor rate - OS. (S= \$.2331/lb.)
- 19. PSMRCON - Packing and shipping material rate - CONUS.
(S= \$.0497/lb.)
- 20. PSMROS - Packing and shipping rate - OS. (S= \$.0620/lb.)
- 21. RAC - Annual supply management cost for assembly. (S= \$104.20/
item/yr)
- 22. RPC - Annual supply management cost for part.
(S= \$104.20/item/yr)
- 23. SA - Annual base supply line item inventory management
cost. (S= \$20.20/item/yr)
- 24. SR - Average manhours per failure to complete supply
transaction records. (S= .25 hours)
- 25. SRICON - Shipping rate (CONUS base to SRA or vice versa via
airlift.) (S= \$.0894/lb.)
- 26. SRIOS - Shipping rate (OS base to SRA or vice versa via
airlift). (S= \$.33092/lb.)
- 27. SRNCON - Same as 25 via surface. (S= \$.0294/lb.)
- 28. SRNOS - Same as 26 via surface. (S= \$.0759/lb.)
- 29. TD - Average cost per original page of technical
documentation (does not include reproduction costs).
(S= \$220.00/page)
- 30. TR - Average manhours per failure to complete trans-
portation transaction forms. (S= .16 hours)
- 31. TRB - Annual turnover rate for base personnel. (S= .33)
- 32. TRD - Annual turnover rate for depot personnel. (S= .15)
- 33. UE - Unit equipment. (aircraft/base, etc.)
- 34. UR - Utilization rate. (flying hours/month)

Propulsion System Peculiar Variables

1. ARBUT* - Engine Automatic Resupply and Buildup Time in months.
2. BP* - Base engine repair cycle time in months.
3. CMRI* - Combined Maintenance Removal Interval. Average engine operating hours between removals of the whole engine.
4. CONF - Confidence factor reflecting the probability of satisfying a random demand for a whole engine from serviceable stock to replace a removed engine. (S= 0.90)
5. DP* - Depot engine repair cycle time in months.
6. ENRTS - Fraction of removed whole engines which must be returned to the depot for repair/overhaul.
7. EOH - Average cost per overhaul of the complete engine at the depot expressed as a fraction of the engine unit cost (EUC) including labor and material consumption. Repair and stockage of engine components considered elsewhere as FLUs is not included.
8. EPA - Number of engines per aircraft.
9. ERMH - Average manhours to remove and replace a whole engine including engine trim and runup time.
10. EUC - Expected Unit Cost of a whole engine.
11. FC - Fuel cost per unit. (S= \$0.423/gallon for JP4; \$0.496/gallon for aviation gas)
12. FR - Fuel consumption rate of one engine in units per flying hour.
13. LS - Number of stockage locations for spare engines.

* Reference AFM 400-1, Volume I, Chapter 7 and Atch 1 for complete description of the Engine Pipeline (Flow Cycle) and use of these terms.

System

1. BCA - Total cost of additional items of common base shop support equipment per base required for the system.
2. BLR - Base labor rate. (S= \$11.70/manhour)
3. BPA - Total cost of peculiar base shop support equipment per base required for the system which is not directly related to repair of specific FLUs or when the quantity required is independent of the anticipated workload.
4. DCA - Same as 1 for depot.
5. DLR - Depot labor rate. (S= \$12.44/manhour.)
6. DPA - Same as 3 for depot.
7. FLA - Total cost of peculiar flightline support equipment and additional items of common flightline support equipment per base required for the system.
8. N - Number of different FLU's within the system.
9. SMH - Average manhours to perform a scheduled periodic or phased inspection of the system.
10. SMI - Flying hour interval between scheduled periodic or phased inspection of the system.
11. SYSNOUN - Name of the system - up to 20 alpha-numeric characters.
12. TE - Cost of peculiar training equipment required for the system.
13. XSYS - System identification - the five character alpha-numeric Work Unit Code of the system.
14. YI - Depot level instruction and training material cost. (\$/man-wk)
15. ZI - Same as 14 for base level. (\$/man-wk)

FLU

1. BCMH - Average manhours to perform a shop bench check, screening and fault verification on a removed FLU prior to initiating repair action or condemning the item.
2. BMC - Average cost per failure for a FLU repaired at base level for stockage and repair of lower level assemblies expressed as a fraction of FLU unit cost.
3. BMH - Average manhours to perform base shop maintenance on a removed FLU including fault isolation, repair and verification.
4. BRCT - Average base repair cycle time in months. The elapsed time for a RTS item from its removal until return to base serviceable stock. (S= .13 months)
5. COND - Fraction of removed FLUs expected to result in condemnation at base level.
6. CS - Cost of software to utilize existing ATE for the FLU.
7. DMC - Same as 2 for depot.
8. DMH - Same as 3 for depot.
9. DPL - Depot repair pipeline time. (months)(S= 1.5-2.0 months)
10. DSS - Depot safety stock level time. (months) (S= .5 months)
11. FD - Total cost of new depot facilities to be constructed for maintenance of the FLU.
12. FF - Same as 11 for base level.
13. FLUNOUN - Word description or name of FLU - up to 16 alpha-numeric characters.
14. H - Number of technical data pages required at depot level.
15. IH - Cost of interconnecting hardware to utilize existing ATE for the FLU.
16. IMH - Average manhours to perform corrective maintenance of the FLU in place or on line including fault isolation, repair and verification.
17. J - Same as 14 for base level.
18. K - Number of line items of peculiar shop support equipment used in repair of the FLU.

FLU

- 19. MTBF - Mean time between failures. (hrs)
- 20. NFLU - Number of FLUs in the weapon system.
- 21. NHA - Next higher assembly. Name of system to which FLU belongs - same as SYSNOUN.
- 22. NRTS - Fraction of removed FLUs expected to be returned to depot for repair.
- 23. PA - Number of new "P" coded reparable assemblies within the FLU.
- 24. PAMH - Average manhours expended on the complete system for preparation and access for the FLU; for example, jacking, unbuttoning, removal of other units and hookup of SE.
- 25. PP - Number of new "P" coded consumable items within the FLU.
- 26. QPA - Quantity of like FLUs within the parent system.
- 27. RIP - Fraction of FLU failures which can be repaired in place or on line.
- 28. RMH - Average manhours to fault isolate, remove, and replace the FLU and verify restoration of the system to operational status.
- 29. SC - Subunit cost; cost of repair material per repair task.
- 30. SP - Number of standard parts within the FLU which will be managed for the first time at bases where the system is deployed.
- 31. UC - Expected unit cost of the FLU at time of initial provisioning.
- 32. UF - Ratio of operating to flying hours for the FLU.
- 33. W - FLU unit weight. (lbs.)
- 34. XFLU - FLU identification - the five character alphanumeric Work Unit Code for the system.
- 35. YD - Duration of depot level training course. (weeks)
- 36. ZD - Same as 35 for base level. (weeks)

Support Equipment Variables

1. BUR - Combined utilization rate for all like items of support equipment - base level.
2. CAB - Cost per unit of peculiar support equipment for the base shop.
3. CAD - Same as 2 except refers to depot support equipment.
4. COB - Annual cost to operate and maintain a unit of support equipment at base level expressed as a fraction of the unit cost (CAB).
5. COD - Same as 4 except refers to depot support equipment.
6. DOWN - Fraction of downtime for a unit of support equipment for maintenance and calibration requirements.
7. DUR - Same as 1 except refers to depot support equipment.
8. NSE - Number of pieces of SE required for FLU.
9. XSE - SE identification - up to 20 alpha-numeric characters.

ORLA

1. K1 - Ratio of probable hardware efficiency to design potential. Use 1.0 if MTBF is an accurate assessment of operational environment.
2. K2 - Ratio of total removals to relevant failures (actual failures versus test failures).
3. K4 - Ratio of demands (removals) to failures.
4. PWRCON - Ratio of packaged to unpacked weight - CONUS.
5. PWROS - Same as 4 for OS (ISC uses a standard value of 1.35 for CONUS and OS).
6. SW - Subunit weight. Weight of repair material per repair task (lbs.)
7. W - Number of base level personnel to be trained per location.
8. X - Same as 7 for depot.

MOD-METRIC

1. ALC - Letter designation of responsible Air Logistics Center:
F Sacramento
G Ogden
H Oklahoma City
L Warner-Robins
P San Antonio
2. PLT - Procurement lead time. (months)
3. YMTBD - Mean time between demands. (hours)
4. BSTART - A factor, usually 1.0, which is multiplied times the expected pipeline cost to determine the starting budget.

VITA

Paul Emerich Taibl was born 1 May 1946 in Baltimore, Maryland. He graduated from high school in Milwaukee, Wisconsin in 1964 and attended the United States Air Force Academy from which he received a commission in the USAF in June 1968. He completed pilot training at Vance AFB, Oklahoma in September 1969 and has had subsequent assignments in the 9th and 20th Military Airlift Squadrons, Dover AFB, Delaware, the Defense Language Institute, Washington, D.C., and the 21st Tactical Air Support Squadron, Tan Son Nhut AB, SVN. In May 1975 he entered the School of Engineering, Air Force Institute of Technology. He is married and has two sons.

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20. Columbus Laboratories, to conceptualize a framework in which specific mathematical models would interact in a logistics support context. LSC, ORIA and MOD-METRIC are three of the Air Force models proposed for SCALE integration. They contain considerable overlap in input requirements and lack a working vehicle for resolving model-to-model inconsistencies. This study shows that a FORTRAN-based consolidation routine reduces input requirements by one third and allows the user to build a single data array that can be accessed by any of the models. The input routine also facilitates the use of certain key outputs (described) which make it advantageous to integrate the models in a sequential fashion. The report includes an analysis of the models, the routine and a user's guide.
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INTEGRATING OPTIMUM REPAIR-LEVEL ANALYSIS AND INVENTORY

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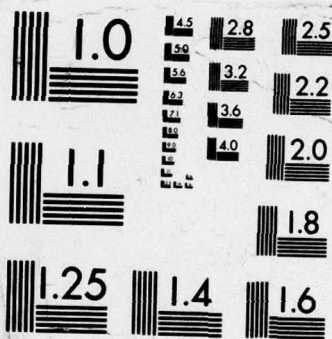
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